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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ATTENTION AND LEVELS OF PROCESSING submitted by STEVEN STUART DENNIS in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in SPECIAL EDUCATION.

ABSTRACT

Three main experiments examined hypotheses about the relationship between levels of processing and attention as described by Johnston and Heinz (1978) and Craik and Lockhart (1972), including an application of this work to a study of attentional factors related to reading proficiency. The major hypotheses tested were that: (1) breadth of attention or sensitivity to nontarget inputs differentially increases with depth of processing (Johnston & Heinz, 1978); (2) the expenditure of processing capacity or cognitive effort increases with depth of processing (Craik & Lockhart, 1972; Johnston & Heinz, 1978); (3) poor readers are distracted by competing verbal inputs (Ross, 1976), and (4) poor readers are less efficient processors of verbal information (Daneman & Carpenter, 1980; Perfetti & Lesgold, 1978).

Study one, which consisted of two parts, examined the effects of depth of processing and nontarget density on breadth of attention as measured by percentage recognition of nontarget words. In part A, subjects were required to detect designated target words within a list of nontargets on the basis of either a sensory or semantic cue. Nontarget density was manipulated by presenting a single word list or two word lists simultaneously and binaurally. In Part B, the two list conditions were replicated with two different groups except that subjects focused their attention on one list while attempting to ignore the second list. The results

in both parts A and B indicated superior recognition memory following semantic analysis but breadth of attention or sensitivity to nontarget items did not increase more in a semantic mode, neither when attention was divided nor focused. Contrary to Johnston and Heinz (1978), it was suggested that if "deeper" levels of analysis require more processing capacity then *less* breadth of attention may result in a semantic mode because less residual capacity would be available for nontarget processing.

Study two assessed the cognitive effort demands of sensory and semantic processing in a similar selective listening task by measuring the magnitude of accelerative heart rate change that occurred in a fixed-foreperiod paradigm. For three groups of subjects, heart rate to targets and nontargets were compared across two levels, involving the provision of sensory cues, semantic cues, and combined sensory/semantic cues. Heart rate results indicated complex qualitative differences between levels that could not readily be discriminated quantitatively in the magnitude of heart rate acceleration although accelerative heart rate was greater to targets than nontargets within each level. Furthermore, subjects appeared to use mixed processing strategies when both levels cues were available for target selection. Either subjects tended to process the words using a sensory cue in some instances and a semantic cue in others, or some subjects tended to predominantly use a sensory cue while others preferred a semantic mode.

Conditions under which heart rate may serve as an index of cognitive effort were discussed.

Study three examined whether poor, average, and proficient readers, aged 9-11 years, differed in selective efficiency and cognitive effort as a function of level of processing and presence of a verbal distractor in a selective listening task. One-half of 60 subjects, equally represented across the three levels of reading proficiency, were each required to select designated targets from nontargets on the basis of a sensory or semantic cue, and in the presence or absence of a verbal distractor. Reaction time to a secondary task was used to measure cognitive effort and the percentage of target omissions or intrusions indexed selective efficiency. The results indicated that, for all groups, cognitive effort increased and selective efficiency decreased at a deeper semantic level, and efficiency improved with increased effort when task difficulty was greatest. These results support the hypothesis linking effort and depth of processing. Furthermore, all readers showed a greater expenditure of effort and a greater frequency of omission errors when a distractor was presented. Poor readers were no more distracted than were average or proficient readers. However, significant differences between the reading groups were observed at deeper levels of processing. Comparisons showed that poor readers missed more targets and invested less effort when processing in a semantic mode. These results

were interpreted as support for the hypothesis that poor readers process verbal information less efficiently, or they may not be aware how to effectively distribute their attentional resources.

Further discussions considered the role of cognitive effort in breadth of attention, selective efficiency, memory performance, and reading skill.

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I. INTRODUCTION

The concept of attention is most closely linked to the notion that man's ability to process information is restricted by a central system of limited capacity (Broadbent, 1971; Massaro, 1975). The amount of information that can be processed at any one time is finite, and when attention is devoted to one mental operation, it is usually done so at the expense of another (Keele, 1973).

Initial theories described this central system as a single limited capacity channel with a structural filter located at some fixed point within a sequence of processing stages (e.g., Broadbent, 1958; Deutsch & Deutsch, 1963; Norman, 1968). The filter was located early in the sequence in some theories (e.g., Broadbent, 1958) and later in others (e.g., Deutsch & Deutsch, 1963) but always at some relatively fixed point. Overall, empirical evidence did not favor this viewpoint because capacity limitations could be found at different locations (Kahneman, 1973; Keele, 1973), and some processes apparently could be performed simultaneously or in parallel with others (Hasher & Zacks, 1979).

Two alternative "capacity" theories were subsequently proposed, each commonly emphasizing the flexibility of the system (Kerr, 1973). One theory proposed that attention could be committed flexibly to any stage of processing, such as the early encoding stage, depending upon task demands (Kahneman, 1973). The second theory suggested that only some

mental operations required attention (Keele, 1973; Hasher & Zacks, 1979; Posner & Keele, 1970). The term attention has been used in these theories to refer to the limited capacity or pool of "effort" or resources available to initiate and maintain some cognitive operations or processes (Johnston & Heinz, 1978).

These capacity models prompted several lines of research: whether capacity limitations were general or specific to particular cognitive operations (Keele, 1973), at what stage of processing limitations arose (Kerr, 1973), or how attention influences various cognitive control processes (Griffith, 1976). From this broad field of research two theories have emerged which link attention to the "depth" of perceptual analysis at which information is processed (Craik & Lockhart, 1972; Eysenck & Eysenck, 1979; Griffith, 1976; Johnston & Heinz, 1978). Here depth refers to the level of processing, ranging from sensory analysis of the inputs to elaboration at a semantic level.

The notion of depth in levels of processing was originally proposed as a framework for human memory research (Craik, 1979; Craik & Lockhart, 1972). The amount of processing capacity or attention "paid" to a stimulus was identified as one criterion of depth (Craik, 1973) but the role of attention was less an issue. The hypothesis that depth of analysis is a major determinant of memory performance provided the prime focus of research (e.g., Parkin, 1979).

Recently, Johnston and Heinz (1978) employed the levels of processing framework to study selective attention. They showed that relevant inputs or targets could be selected from irrelevant inputs or nontargets at either a sensory or semantic level of processing but the consequences for selective efficiency, and the amount of capacity required, differed at each level. Specifically, as the system shifted from a sensory to semantic mode, increased capacity expenditure and greater breadth of attention or greater awareness or recognition of irrelevant inputs resulted, and selective efficiency decreased. Furthermore, they showed that when target selection could be accomplished with either a sensory or semantic cue, no more capacity was consumed than when only a sensory cue was available. Subjects could flexibly choose the most efficient processing mode.

Johnston and Heinz attributed greater breadth of attention to deeper levels of perceptual analysis. More information would be collected from nontarget sources at a semantic level of perceptual processing, and selection accuracy would suffer. This hypothesis was tested indirectly by comparing the capacity demands of sensory and semantic modes of selection when the nontarget density was increased. They found that increasing the number of nontargets placed more demands upon available capacity for semantic than sensory selection. However, such an effect could have resulted if the semantic items were less discriminable in the divided attention procedure since it would take more

effort to distinguish between them (Eysenck & Eysenck, 1979).

A more direct test could be made by measuring incidental learning of nontarget items. If more information is extracted from nontargets in a semantic mode when nontarget density is increased, then retention of these items should exceed retention of sensory items. The breadth hypothesis would require that an interaction occur between nontarget density and level of processing. Specifically, as density increases a proportionately greater percentage of nontarget items should be retained following semantic analysis beyond the difference that may be accounted for by the levels factor alone.

To test the hypothesis that processing capacity demands increase from a sensory to semantic mode, Johnston and Heinz (1978) used the secondary task technique (cf. Kerr, 1973). The procedure requires subjects to perform a secondary task, such as a simple reaction time to a probe stimulus, during the course of performing a primary task of interest. Here the primary task required subjects to detect designated target words on the basis of either a sensory or semantic cue. The secondary task required a reaction time response to brief intermittent presentations of a light signal. It is reasoned that as the capacity demands of the primary task increase, less residual capacity will be available for responding to the secondary task, and longer latencies will result. Several authors (Duncan, 1980; Kahneman, 1973; Kerr,

1973) have suspected that introduction of the secondary task may alter or interfere with the processing demands of the primary task. This problem is compounded further by the difficulty of establishing whether negative interference occurs (Duncan 1980).

Given the importance of the concept of processing capacity to theories of attention (Johnson & Heinz, 1978; Kerr, 1973) and memory (Craik & Lockhart, 1972; Hasher & Zacks, 1979), efforts to find a valid measure of processing capacity, or attempts to validate the secondary task technique, would seem paramount. One solution to this problem is suggested by recent evidence that phasic heart rate changes can be used to index processing capacity (e.g., Coles & Duncan-Johnson, 1975; Dennis & Mulcahy, 1980; Shangi, Das, & Mulcahy, 1978; Tursky, Schwartz, & Crider, 1970). Since a physiological measure would not interfere with performance on the primary task, variations in the capacity demands would be unique to the primary task. Applied within the selective attention paradigm of Johnston and Heinz, this procedure would provide a further test of the hypothesized relationship between attention and levels of processing, as well as serve to validate the secondary task technique.

Johnston & Heinz (1978) also noted that Ss adopted a sensory mode when both sensory and semantic cues were available for target selection. Presumably, the perceptual processing system can be flexibly shifted to the processing

mode which best suits the task demands; minimizing capacity expenditure yet maintaining accurate selection. Other evidence, however, suggests that semantic information will be extracted even when a sensory cue is available (Nelson, Walling, & McEvoy, 1979). Whether the system is flexible or constrained in some fashion can be assessed directly by comparing phasic heart rate changes between a condition providing both sensory and semantic cues to conditions providing access to only one selection cue. The processing mode adopted in the combined sensory/semantic condition will be indicated by the approximation of the heart rate pattern to those patterns observed in the sensory-only and semantic-only conditions.

The study of attention and levels of processing may also be seen to have important implications for more applied problems. One of these concerns the relationship between selective attention and reading disorders. In a number of recent reviews (Douglas & Peters, 1979; Krupski, 1980; Ross, 1976) a selective attention deficit has been implicated as a major problem with children experiencing problems in learning and reading. Empirical evidence to date, however, has not been decisive on this issue. Studies supporting the deficit hypothesis, whether they examined learning performance outcomes on cognitive tasks (Denny, 1974; Hallahan, Kaufman, & Ball, 1974) or reading tasks (Singer, Samuels, & Spiroff, 1973; Willows, 1974) have been compromised by studies attributing the observed effect to

processes other than attention (e.g., Pelham, 1979; Pelham & Ross, 1977; Torgesen & Goldman, 1977). Part of the difficulty, as noted by Ross (1976), is that measures of learning confound attention with other variables, primarily aptitude and memory. Other problems result when attentional deficiencies are found on some tasks and not others (Pelham, 1979). Contradictory findings may be due to the possibility that poor readers only experience difficulties with certain kinds of materials or tasks which emphasize particular modes of processing (Krupski, 1980). For example, some evidence exists to suggest that poor readers are particularly sensitive to distractors embedded within the task as opposed to being peripheral (Douglas & Peters, 1979).

Other researchers have suggested that with a failure to develop automaticity in the preliminary processing stages of reading, such as phonological encoding, the amount of processing capacity available for higher order processes, such as comprehension, is reduced for the poor reader (LaBerge & Samuels, 1974; Perfetti & Lesgold, 1978). Assuming further that the processing and storage of words in "working memory" (Baddeley & Hitch, 1974) requires capacity, then retention of items also may be reduced. "As the amount of attention required to identify incoming items increases, the amount available to maintain storage decreases" (Curtis, 1980, p. 657). Preliminary evidence for this attention demand hypothesis has indicated that verbal coding processes are slower or more inefficient for the poor reader but

little direct evidence that poor readers differ in their effort allocation has been presented.

The paradigm adopted by Johnston and Heinz (1978) seems to possess several advantages as a method for studying the relationship between attention and reading. The paradigm employs an auditory selection task requiring two levels of processing. Whether selection deficits are general or specific to a particular mode could be assessed. Secondly, the measures of processing capacity and selective efficiency do not require inference from changes in learning. Both measures coincide with the temporal deployment of attention, and each measure is less likely to be sensitive to group differences in mnemonic or problem-solving abilities. Furthermore, the use of such measures would permit a direct assessment of effort allocation by poor readers that is a crucial element in the attention demand hypothesis described above.

Confirmation of the hypotheses linking attention to levels of processing would provide useful data in a number of ways. Generally, it would increase our understanding of the relevance of levels of processing to attentional and memorial processes. The level at which stimuli are encoded has a remarkable impact upon retention (Craik, 1979), and it would be valuable to understand the role played by attention. Similarly, we might achieve some insight into the effect of levels on selection processes and breadth of attention, and its relationship to reading. Our ability to

select some inputs and ignore others would seem, intuitively at least, to vary according to the mode of selection used, and the amount of central processing capacity required to exercise that mode. Additionally, the empirical validation of measures of processing capacity would ensure the testability of some aspects of levels theory, and the hypotheses which it has generated.

The series of studies to be presented here represent an attempt to investigate further the relationship between attention and levels of processing. Study one consists of two parts. Part A examined whether greater breadth of attention results when deeper levels of perceptual analysis are used in a divided attention paradigm. This study was partially replicated in Part B using a focused attention paradigm. The use of two different attentional paradigms would permit a statement about the generality of the findings. Incidental recognition memory served as an index of breadth of attention in both parts of study one. Study two examined whether demands on central processing capacity, as indexed by phasic heart rate changes, increase from a sensory to a semantic mode of processing, and whether a sensory or semantic mode is selected given the availability of both cues. Recognition memory was also assessed in order to further replicate the findings of study one. Study three applied the levels of processing model of attention to the question of the relationship between reading proficiency and attentional factors.

II. SELECTED REVIEW OF THE LITERATURE

Components of Attention

Attention is a generic term encompassing a broad class of "internal" processes which significantly influences events from stimulus reception to response execution (Kahneman, 1973). In its simplest form attention means the faculty of noticing but this definition soon gives way to many permutations of operational definitions demanded for experimental precision (e.g., Treisman, 1969). In spite of these operational complexities, however, the construct does appear to be captured by reference to three components, including alertness or arousal, selectivity, and processing capacity (Posner & Boies, 1971; Pribram & McGuiness, 1975). Taxonomies for understanding the construct have made reference to other aspects (for example, see Krupski, 1980) but arousal, selectivity and capacity appear to comprise three essential components.

Arousal may be defined physiologically as a phasic response to input. Momentary or phasic changes in arousal typically occur in response to stimulus changes, thereby enhancing the faculty of noticing. In other words, arousal influences the registration of input into awareness. Novel or contrasting stimuli, for example, will usually produce a behavioral orienting response reflected physiologically by shifts in arousal (Lynn, 1966).

In a review of the neural systems involved in attentional processes, Pribram and McGuiness (1975) also

described a second physiological mechanism, called activation. This system of activation or readiness to respond may be reflected physiologically by a tonic change or a relatively enduring change in normal base levels (e.g., minute-long changes in heart rate). Activation involves the intent to do something about the incoming stimuli; in decision-making and in preparing to respond. Thus, while arousal may be seen as stimulus-driven, activation is largely response-driven. However, both phasic and tonic aspects are regarded, generally, as involuntary, reactive mechanisms that may, in turn, be modulated via the intentional effort exercised by the individual (Kahneman, 1973; Pribram & McGuinness, 1975).

Selective attention refers to "... the taking possession by the mind, in clear and vivid form, one out of what seem several simultaneously possible objects or trains of thought" (James, 1966, p. 5). Selection so defined emphasizes the voluntary , active nature of focusing on some inputs to the exclusion of others. This aspect, however, may be defined more explicitly in terms of what is being selected. Selecting inputs from a particular source, targets of a particular type, attributes of an object, or responses in a particular category are four common selection modes (Treisman, 1969). In each instance, selection is necessary in order to contain the flow of information.

The third essential element, and the component of primary interest in the present work, is processing

capacity. The processing of information, including the act of attending itself, requires cognitive effort or the expenditure of processing capacity (Pribram & McGuiness, 1975). This resource may be likened to a "pool" of psychological effort (Kahneman, 1973) which can be allocated or time-shared among various mental operations (Posner & Boies, 1971). Effort is involved whenever an organism modulates the interplay between input and response, engaging each system in order to control the flow of incoming signals and the responses which may follow (Pribram & McGuiness, 1975). The term capacity as it is used in theories of attention is distinct from the notion of storage capacity as it relates to limitations of various memory systems. Short-term memory for seven plus or minus two items is a classic example of a storage capacity limitation (Miller, 1976). In contrast, processing capacity refers to the "...limited pool of energy, resources, or fuel by which some cognitive operations or processes are mobilized and maintained" (Johnston & Heinz, 1978, p. 422). The role of processing capacity in various theories of attention will be discussed in the next section.

Attention and Information Processing

The study of attention may be understood in context of a general model of information processing. The basic model to which most theorists adhere consists of a three stage hierarchical sequence (Massaro, 1975). The sequence begins as sensory representations of the external stimulus inputs,

such as the physical features of a word, are detected and stored briefly in a sensory register. These inputs may then excite their representations in memory; that is, they are encoded and recognized. While the integrity of the inputs are maintained by a short-term memory buffer, those representations which bear relevance to the context of the attended task may be further elaborated, and if necessary, transfered to long term memory before a response choice is made. Using a simple analogy, each stage may be said to ask a different question. Stage one detection asks, "Is something there?". The question at stage two recognition is, "What is it?", and stage three response selection asks, "What is to be done?".

Three theoretical alternatives about how attention, as a limited capacity system, operates within this general processing model have been proposed . The first of these, single channel theory (e.g., Broadbent, 1958), proposes that incoming signals are subjected to a filter at a fixed stage in the sequence. The filter is intended to reduce the volume of incoming signals to a manageable level. The location of the filter has been postulated to follow stage one (Broadbent, 1958), stage two (Deutsch & Deutsch, 1963; Norman, 1968) or both stages, depending upon the type of input attended to (Broadbent, 1971; Treisman, 1969). Inputs processed at any point prior to the filter are not subject to any capacity limitations; that is, processing of all inputs may occur in parallel, whereas, serial processing

follows as capacity is allocated to one input at a time.

These structural or fixed processing theories have not proved acceptable. Particular inadequecies were found with each theory (see Massaro, 1975) but in sum, the bulk of evidence failed to support a fixed point. Capacity limitations could be found at each of the three stages (Kahneman, 1973). Subsequently, two alternative theories were proposed about how the limited capacity of the system influenced the processing of information (Kerr, 1973). Some theorists proposed a differentiated system whereby only some mental operations might require the expenditure of capacity Keele, 1973; Kerr, 1973). Operations that never appear to require capacity may proceed in parallel or simultaneously with those operations that do require capacity. Evidence that encoding or tagging an input to its representation in memory does not require processing capacity but rehearsal and responding do (Kerr, 1973; Posner & Boies, 1971) supports this position. However, some exceptions have been noted. Well patterned responses may occur with no apparent drain of the limited capacity system whereas encoding of weak signals may require a considerable amount of conscious effort (Posner & Snyder, 1975).

The second hypothesis adopted by many theorists proposes an undifferentiated system whereby capacity can be allocated flexibly to different stages or types of processing (Kahneman, 1973; Posner & Snyder, 1975). Unlike the structural position where selection was determined by

the presence of a filter, both the differentiated and undifferentiated capacity theories presume that the system operates in response to task demands. It permits selection to occur at any point along the continuum of perceptual processing of early sensory to late semantic representations of the inputs. The limited capacity can be allocated to various tasks concurrently, with interference occuring when task demands exceed available capacity.

As a consequence of these "capacity" models, attempts have been made to investigate the attentional correlates of different levels of processing where the task demands are defined by the continuum of processing from sensory to semantic levels of perceptual analysis (e.g., Johnston & Heinz, 1978). By so doing, a better understanding of the role of attention in the selection of relevant from irrelevant inputs, memory performance, and in general, learning, might be achieved (Posner & Snyder, 1975).

The study of levels of processing has proceeded along two convergent lines. The more recent one, called multimode theory, assesses the attentional correlates of different levels or modes of processing and its influence upon selective processes (e.g., Johnson & Heinz, 1978), and the other investigates the effect of levels on subsequent memory performance (e.g., Craik & Lockhart, 1972). The two levels of common interest represent, in themselves, stages within the general model of information processing. These include the sensory and semantic levels of perceptual analysis.

Where the two approaches differ concerns the paradigms and dependent measures. Multimode theory examines measures of capacity and selective efficiency within a selective attention paradigm. A levels of analysis approach to memory, on the other hand, typically measures retention of items within an incidental learning paradigm. Each of these models and related research will be reviewed in the next section.

Attention and Levels of Analysis

The "levels of analysis" framework for the study of human memory was initiated by Craik and his associates (e.g., Craik, 1973; 1979; Craik & Lockhart, 1972; Craik & Tulving, 1975). The original formulation proposed that information may be encoded along a continuum of perceptual analyses arranged hierarchically from sensory analysis of the physical characteristics of the inputs through successive analyses culminating at semantic processing. Three focal points on this continuum, describing physical, phonemic, and semantic levels, define the stimulus attributes which are processed, with analysis at each succeeding level assumed to be "deeper" or more elaborative than the previous one. How well information is remembered, or the permanance of the memory trace (Craik, 1973), is assumed to be a function of this depth of analysis. Items processed at a semantic level will be remembered better than those items analyzed for their sensory qualities.

In Craik and Lockhart's (1972) original formulation, depth implied that a greater degree of cognitive analysis

was performed on the stimulus. Subsequently, Craik (1973) proposed that three factors determined depth of processing: "(1) stimulus salience or intensity; (2) the amount of processing devoted (or the amount of attention paid) to the stimulus; and (3) the item's meaningfulness or compatibility with the analyzing structures" (p. 50). Thus, attention plays an important role since increased depth or shifts from a sensory to semantic mode of encoding would require that more cognitive effort be devoted to the analysis.

The majority of empirical studies on the effect of levels upon memory performance have, by and large, supported the hypothesis that increased depth results in better retention of the inputs (e.g., Parkin, 1979), with the qualification that several other factors, operating in an interactive fashion with initial level of encoding, affect retention. The intent to remember (Postman & Kruesi, 1977), the type of retrieval cue (Fisher & Craik, 1977), and the type of rehearsal (Goldman & Pelligrino, 1977) represent some important variables. Subsequent revisions of the levels framework incorporated evidence indicating that processing may occur at any level of analysis; that is, it need not proceed hierarchically, with elaborative processing occurring within any level on the continuum (Craik, 1979; Craik & Jacoby, 1975; Lockhart, Craik, & Jacoby, 1975).

In contrast to the extensive literature concerning levels of processing and memory performance, the proposed relationship between depth and the expenditure of processing

capacity, and the influence of cognitive effort on subsequent memory performance, is less understood. But understanding the role of effort has become increasingly important, especially in light of several criticisms of the levels of analysis framework. The concept of depth has been criticized on theoretical grounds primarily because no independent measure by which to order different tasks along the continuum has been found (Nelson, 1977). Similar arguments were made by Eysenck (1978) and Baddeley (1978) who added that the specified levels seemed rather arbitrary, nonscientific categories.

While the latter argument may be countered by pointing to the importance of sensory and semantic levels of processing to general models of information processing (Marazzo, 1975), as well as specific models of reading (Cooper, 1972), failure to find an independent index of depth is theoretically problematic. Previous attempts to index depth by retention performance presents a problem of circularity (Shangi, Das, & Mulcahy, 1978), and using total time to process inputs as an index (e.g., Walsh & Jenkins, 1973) has not proved adequate. A task may require considerable time to complete yet involve little cognitive effort (Tyler, Hertel, McCallum, & Ellis, 1979), and differences in total processing time may be due to factors unrelated to the differences in memory performance associated with each level of analysis (Parkin, 1979).

In recognition of these problems, two other methods have since been tested as potential candidates, and both appear to be measures of cognitive effort. Based on a theory by Lacey (1959; 1967) that phasic heart rate (HR) changes reflect attentional processes, Shangi et al. (1978) employed this physiological measure. Their results showed that, relative to a sensory level of analysis, encoding at a semantic level is associated with a greater magnitude of accelerative HR change. Although this research has not yet been replicated in a levels of analysis paradigm, HR data from other investigations suggest that the magnitude of accelerative HR change may serve as an independent index of cognitive effort (Dennis & Mulcahy, 1980), and depth.

The second method involves the use of secondary reaction time (RT) to a probe stimulus as a measure of effort. This technique, originally devised by Johnston, Greenberg, Fisher, and Martin (1970), requires subjects to perform two tasks concurrently; a primary task of interest and a second task requiring a RT response to a random, intermittent probe stimulus, such as a light or tone signal. It is reasoned that as the primary task demands increase, less residual capacity will be available for responding to the probe signal and longer latencies will result (Kerr, 1973). This procedure has since been used in a levels of analysis framework in a limited number of studies, with the fairly consistent result that more effort was devoted to the primary encoding task; that is, secondary reaction times

were slower, as depth of processing increased (Mulcahy & Dennis, note 1; Eysenck & Eysenck, 1979).

These results suggest that a behavioral or physiological metric of cognitive effort could serve as an independent index of depth although it is recognized that the concept of depth also makes reference to the factors of stimulus salience and meaningfulness. However, others have suggested that effort is distinct from level of processing on the basis that effort can be orthogonally or independently varied within any level (Tyler et al. 1979). But this position fails to recognize that effort is one criterion of depth (Craik, 1973), as well as the fact that manipulations of effort independent of level of processing does not provide evidence contrary to the proposed relationship. Rather, it is suggested that the relationship between cognitive effort and depth of analysis, while it remains relatively unexplored in a levels of analysis framework, is important to an understanding of the role of attention in levels of processing. Memorability is linked to depth of encoding, and since cognitive effort is one criterion of depth, further investigations of the role of effort in levels of analysis would address concerns expressed about the notion of depth as a theoretical construct, as well as the nature of the relationship between cognitive effort and human memory performance.

Attention and Multimode Theory

A more recent approach to the study of levels of processing, represented by the work of Johnston and Heinz (1978; 1979) has focused on the effects of depth of processing upon the expenditure of processing capacity and selective attention, "... a process whereby perception is biased toward or against specific inputs" (1978, p. 422). In terms of the expenditure of processing capacity, Johnston and Heinz proposed that capacity demands increase from a sensory to a semantic mode since, at deeper levels of processing, the number or complexity of cognitive operations perfomed on a particular input increase. Several tests of this hypothesis were conducted using an attention task requiring subjects to select designated target works from nontargets presented auditorally. Target items could be selected on the basis of either a sensory cue or a semantic cue, and in some instances, both cues were provided. Processing capacity allocated to the selection task was measured by response latencies to a secondary RT task requiring the detection of light signals presented concurrently with the selection task. In each of five experiments, Johnston and Heinz showed greater capacity expenditure at deeper levels of processing. Similar sensory/semantic effort differences also were reported by Eysenck and Eysenck (1979) who further demonstrated, in addition to the work by Tyler et al. (1979), that cognitive effort increases as the amount of processing or elaboration

within a level is increased. Again, these results are consistent with the cognitive effort data generated in response to Craik and Lockhart's (1972) levels of analysis framework for the study of human memory.

Johnston and Heinz also showed in their experiment five that when a target item could be identified on the basis of both a sensory and a semantic cue, no more capacity was consumed than when only a sensory cue was available. Thus, subjects could efficiently deploy attention to meet the task requirements. They were not bound to process at a semantic level when, in fact, it would not be efficient to do so.

While others would support the claim that attention can be flexibly allocated (Kahneman, 1973; Treisman, 1969), it appears to be equally true that exclusive encoding of a single feature or attribute in a levels of processing task is highly unlikely. Much evidence has been presented that,

> "Even though processing may be directed toward a specific type of feature, other attributes are activated. This activation occurs because of task requirements, order of access constraints, or habitual semantic processing" (Nelson, Walling, & McEvoy, 1979).

Craik and Simon (1979) also noted that individuals differ in their propensity to process inputs to deeper levels.

What is of interest then, is the empirical finding by Johnston and Heinz (1978) that provision of both sensory and semantic cues for target selection did not increase the

apparent expenditure of capacity to a somewhat greater degree relative to the condition where only a sensory cue was available. Several explanations seem plausible. Perhaps the semantic features of the inputs were analyzed in the sensory-cue-only condition so that no differences in capacity expenditure were apparent. Alternatively, semantic encoding could have occurred in the combined cue condition but it was minimal, or the secondary RT measure of expended processing capacity was not sufficiently sensitive. In any event, whether encoding operations in a selective attention task are constrained in some fashion, or completely exclusive, can be tested in other ways. Alternative measures of effort, such as heart rate (cf. Shangi et al. 1978) could be tested using similar experimental procedures, or the effect of selection cue on subsequent memory performance could be assessed. In the latter instance, the provision of semantic cues in a combined sensory-semantic condition should result in greater recall or recognition of items relative to a sensory-cue-only condition if subjects encode the semantic features.

Recently, there have been two further criticisms affecting interpretation of the cognitive effort data produced in the selective attention paradigm. The first concerns the problem of confounding factors. It is essential that the tasks representing each level of processing be as equivalent as possible, varying primarily, if not exclusively, in the encoding process. Differences in the

ratio of targets to nontargets representing sensory and semantic levels in the Johnston and Heinz (1978) studies, with a higher proportion of semantic nontargets, could account for the increased effort demands of the semantic task (Eysenck & Eysenck, 1979). Since a greater allocation of available processing capacity may be required to select a target when the number of nontarget alternatives increase (cf. Dennis & Mulcahy, 1980), observed capacity differences may not have been due to a levels effect, but rather due to the former. Alternatively, cognitive effort differences between levels may have been a function of both depth of encoding and task complexity attributable to variations in the number of alternative inputs.

The second criticism concerns the secondary RT measure of processing capacity expenditure. Although this measure has received empirical validation in a number of studies (Kerr, 1973), a recent discussion of this procedure by Duncan (1980) provides a cautionary note. The combination of two tasks, such as target detection and secondary RT may produce specific interference effects. While this would be less of a problem if the effect is the same across levels, differential effects would seriously confound the results. One possible solution would be to test different secondary tasks to determine if specific interference effects occur. This approach was adopted by Eysenck and Eysenck (1979) who found no differential interference effects on a visually presented primary task using both auditory and visual

secondary probe stimuli. Another approach would be to use a measure of capacity which would not require information processing at all. One likely candidate would be a physiological measure monitored simultaneously with the ongoing process of the primary task as was done in the Shangi et al. (1978) heart rate study reported previously. Thus, a nonintrusive physiological measure index of capacity changes comparing similar or equivalent task conditions would provide a further test of the theory linking attention to levels of processing. To the extent that HR corresponds with observed secondary RT latencies, the latter behavioral measure also would receive further evaluation. In a latter section, further evidence will be presented to suggest that the magnitude of accelerative HR change could serve this purpose.

The more unique aspect of multimode theory concerns the effect of depth of processing on selective attention.

> "As the perceptual-processing system shifts from early (sensory) to late (semantic) modes, it collects more information from nontarget sources but requires more capacity to focus on a target source" (Johnston & Heinz, 1978, p. 420).

Thus, selective efficiency will decrease at deeper levels of processing because of a greater breadth of attention or sensitivity to nontarget inputs.

Johnston and Heinz tested the effect of levels on breadth of attention indirectly by determining whether the

capacity demands of sensory and semantic selection were differentially influenced by the density or number of nontargets. By increasing nontarget density they expected to find a greater capacity expenditure and a greater reduction in selection accuracy for semantic selection; two results which they did obtain. However, these results can be explained without attributing greater breadth of attention to a semantic mode of processing. More features of nontarget items would have to be analyzed in order to discriminate the targets when a semantic cue guided the selection process. If the semantic items were less discriminable, then the same effect would result (cf. Keele, 1973). Furthermore, differences in the ratio of targets to nontargets between levels noted previously would compound the effort demands of semantic selection as nontarget density was increased.

Alternatively, the lessened selective efficiency associated with deeper levels of processing may be linked solely to the effort demands of semantic encoding and not to any increases in the sensitivity of the system to nontarget information. To the degree that semantic encoding requires a greater expenditure of capacity, and more stimulus features of both target and any nontarget sources would be analyzed, less residual capacity would be available for any additional processing necessary for accurate target selection. A similar explanation was used by Eysenck and Eysenck (1979) to account for variations in selective efficiency in detecting targets at different levels of processing in

dichotic listening experiments. Subjects can more readily detect targets from nontargets presented in one ear while shadowing or repeating a second message to the other ear if sensory cues are given.

> "If capacity is limited, and if the shadowing task preempts most of the available capacity, then it follows that mainly those targets that can be identified with minimal investment of processing capacity will be detected" (p. 483).

Whether selective efficiency decreases because irrelevant sources of input or nontarget information are more likely to reach conscious awareness in a semantic mode, or simply because of capacity limitations, is an important distinction that needs to be tested more directly. One approach would be to assess the degree of incidental learning of nontarget words as a function of level of processing and nontarget density. To the degree that greater breadth of attention results as a function of depth of processing, more nontarget items should be remembered in a semantic mode when nontarget density is increased. Since recall is typically found to be superior following semantic processing (Parkin, 1979), a proportionately greater percentage of nontarget items should be retained following semantic analysis that cannot be attributed to a levels factor alone. Furthermore, breadth effects should emerge whether attention is divided between competing inputs or focused on one input to the relative exclusion of the other.

This approach would provide further information about the breadth characteristics of different levels of processing.

In both the "levels of analysis" and "multimode" approaches to the study of the relationship of cognitive effort and levels of processing, several indices of cognitive effort have been tested. To date, secondary reaction time to a probe stimulus has proved to be the most adequate although some potential limitations of the method were noted (Duncan, 1980). Since these limitations possibly could be overcome with a physiological measure, the use of heart rate as an index of cognitive effort will be discussed in the following section.

Processing Capacity and the Cardiac Response

The existence of a systematic relationship between cognitive activity and heart rate patterns has been well established (Cacioppo & Sandman, 1978; Coles & Duncan-Johnson, 1975; Tursky, Schwartz, & Crider, 1970). Within a reaction time paradigm, a triphasic pattern has been observed during the preparatory interval between the warning signal and the reaction or respond signal. After an initial deceleration, HR acceleration is followed by a decelerative response which typically reaches its nadir or lowest point within one second of the response signal onset.

Lacey (1959;1967) proposed that the latter biphasic components were indicative of two attentional processes. Tasks requiring attention to the external environment or enhanced sensory sensitivity result in cardiac deceleration;

while tasks requiring internally directed attention result in cardiac acceleration. Coles and Duncan-Johnson's (1975) subsequent refinement of the theory asserted that the accelerative component was associated with the information processing requirements of the task. Deceleration was considered to be a joint function of preparation for stimulus detection and response execution.

Within variations of the RT paradigm, manipulations of various stimulus parameters have been found to alter HR in the predicted manner (e.g., Dennis & Mulcahy, 1980; Coles & Duncan-Johnson, 1975; Higgins, 1971). Tursky et al. (1970) demonstrated that greater cardiac acceleration accompanied more difficult tasks. For instance, greater acceleration occurred when a transformation task requiring adding numbers was difficult, and when subjects responded overtly, rather than covertly. Two other experiments by Coles & Duncan-Johnson (1975) further showed that when subjects made a button press response whenever a series of tones represented a unique pattern, acceleration increased to tones occuring later in the series since these determined whether the pattern was unique. Deceleration depended on the response requirement.

In the most recent work of this type (Dennis & Mulcahy, 1980), a Sternberg (1966) paradigm was used to demonstrate that the magnitude of the accelerative component was influenced by the cognitive processing effort required by a rehearsal task. Subjects presented with a brief visual

display of six digits, followed six seconds later by a single digit, indicated whether this digit was in the previous six digit display. Using three levels of difficulty where the array contained identical (e.g., 222222) or different figures (e.g., 516516 or 495163), the magnitude of the accelerative response was found to correspond to the difficulty level of the rehearsal task. These results are also consistent with the data from the one study which has attempted to index depth of processing with phasic HR changes in a levels of analysis memory task (Shangi, Das, & Mulcahy, 1978). Relative to a sensory level of analysis, encoding at a semantic level was associated with greater accelerative responses under incidental learning conditions although the magnitude of this effect was small.

Developmental studies with children have been supportive of the cognitive-physiological relationship. Stroufe (1971) found, by comparing 6-, 8-, and 10-year-old boys, that older children produced greater and more reliable decelerations, suggesting that age differences reflected a developmental improvement in attentional set. Similarly, Jennings (1971) observed that, with Piagetian tasks, the biphasic components occurred with all cognitive tasks, with an increase in magnitude of change on some tasks requiring higher levels of cognitive performance. Exceptional children who have not attained the same degree of developmental maturity as normals also show less HR change during the preparatory interval of a RT task (e.g., Bower & Tate, 1976;

Stroufe, Sonies, West, & Wright, 1973).

While these preceeding results support the contention that cardiac acceleration covaries with cognitive effort, the findings are complicated by the fact that physiological responses to stress can be quite similar (Kahneman, 1973). Since both response patterns share sympathetic pathways, an accelerative response to more difficult materials may be an artifact of increased stress levels. However, several lines of evidence mitigate the stress related hypothesis. On an intuitive level, it seems more logical to expect a tonic change following a stressful experience and not merely the momentary second-by-second phasic changes described here. Secondly, performing a cognitive task in the presence of a stressor increases stress resistance, thereby lowering HR and improving performance (Vossel & Laux, 1978). If stress had been operative in the study manipulating cognitive effort (i.e., Dennis & Mulcahy, 1980), then lower levels would be expected in latter trials as subjects became accustomed to the task. But no differences between early and late trials were found.

Another line of evidence was provided in a recent study comparing the effects of viewing autopsy slides, the stressful stimuli, with performing arithmetic problems, the cognitive task; each at two levels of stressfulness or difficulty (Cacioppo & Sandman, 1978). Their results showed a linear relationship between difficulty of the cognitive tasks and acceleration whereas none was found for the stress

inducing stimuli.

Finally, if we assume true the hypothesis that children with learning difficulties are, in part, disabled by anxiety reactions to academic material (Buktenica, 1973), then accelerative responses caused by this stress should exceed, if not equal, those of normal children. The fact that they are less (Stroufe et al. 1973) is consistent with the hypothesis that differences in HR levels between the groups reflects variations in their allocation of effort.

The similar patterns of covariation between HR and various cognitive activities suggests that this autonomic response is related to the access or deployment of processing capacity. Therefore, phasic cardiac changes could be used to index physiologically the processing requirements of different levels within a selective attention task. This application would enable operationalization, and physiological confirmation, of capacity on a second measure independent of behavioral RT to secondary probe stimuli (cf. Kerr, 1973). In addition to enhancing construct validity through "multiple operationalism" (Torgesen, 1976), the cardiac response would provide an index of capacity changes during processing without requiring inference from changes in product (cf. Walsh & Jenkins, 1973).

The fact that HR is a physiologically constrained response is the major limitation. Definite physiological boundaries, such as rate and magnitude of change, restrict the type of paradigm where cardiac effects can be observed.

At the same time, however, these paradigms do differ from the type best suited to secondary RT effects. Therefore, generalizabiltiy will be served to the extent that results from different paradigms and measures correspond.

The review to this point has focused on "internal" aspects of levels of processing theory, and it was suggested that further tests of hypotheses linking depth to the expenditure of processing capacity and breadth of attention would shed further light on this subject. Other approaches to the study of attention could, of course, be taken. For example, a levels of analysis or multimode perspective could be applied within a developmental framework (e.g., Manis, Keating, & Morrison, 1980; Snart, 1979) or as a method for studying the attentional behaviors of exceptional learners (Hall, 1980). In the final section of the review, the latter approach is taken because of the importance of understanding how exceptional learners might differ quantitatively, and qualitatively, in their manner of information processing. Specifically, a study of the relationship between the attentional factors of cognitive effort and selective efficiency, and reading proficiency is advocated.

Attention and Reading Proficiency

The idea that poor readers or reading disabled children process information differently from their skilled counterparts has been approached from many different perspectives (for an extensive review see Carr, 1981). Most approaches, however, share in common the notion that the

information-processing system is one of limited capacity (e.g., Atkinson & Shiffrin, 1968; Perfetti & Lesgold, 1978). Thus, the efficiency with which this limited resource is used will play an important role in determining how well knowledge is acquired, retained and transformed within the existing framework of information (Hall, 1980).

This perspective is a predominant feature of theories that suggest poor readers experience a pervasive "verbal deficit" (Vellutino, 1977) that may involve more specific deficits, such as in short-term encoding of linguistic inputs (Daneman & Carpenter, 1980; Perfetti & Lesgold, 1978). This theory or class of theories is based on two assumptions about the information processing system; that information is processed and stored via working memory, and that working memory has a limited capacity.

"Working memory" (Baddeley & Hitch, 1974) refers to a system analagous to a temporary file in a computer system that serves as a site for both information processing and storage functions (LaBerge & Samuels, 1974). It is assumed to be a limited capacity system, both in terms of storage and processing capabilities, and as such, information processing efficiency becomes critical when tasks place heavy demands that approach or exceed the capacity of this system. If, for the poor reader, decoding of verbal or written language has not reached a sufficiently automatic level to free the information processing system for other types of cognitive analyses, such as comprehension, then

substantial differences in proficiency will result (Curtis, 1980; LaBerge & Samuels, 1974). In these instances, differences between poor and good readers will be reflected in a number of ways, such as the amount of attention paid to a stimulus, and the quantity and quality of information extracted (Daneman & Carpenter, 1980). To the degree poor readers process information less efficiently, less information and information of a lower quality will be maintained. A similar view was taken by Perfetti and Lesgold (1978) in their suggestion that unskilled readers are slow and inefficient at storing new items and clearing old items from working memory. In any type of speeded task, or one which taxes the capacity of the information processing system, this inefficiency would produce a back-log of linguistic information that may no longer be relevant to the decisions involved in dealing with new incoming information.

To date, the majority of evidence presented in support of this attention-demand hypothesis has been derived from assessments of short-term retention of the contents of working memory (Goldman, Hogoboam, Bell, & Perfetti, 1980; Perfetti & Goldman, 1976; Daneman & Carpenter, 1980) or the speed with which information can be coded (Curtis, 1980). In each instance, less skilled readers appear to be less efficient in recoding linguistic information. While these results are used to support the notion the poor readers differ in their effort allocation patterns, direct measures of cognitive effort have not been used. However, the results

of developmental studies of age differences in the allocation of processing capacity indicate that various cognitive operations, such as encoding, do become more automatic with experience and require less capacity (Manis, Keating, & Morrison, 1980) and processing time (Guttentag & Haith, 1980). Young children invest more cognitive effort at earlier stages of processing, such as alerting and encoding, while the effort demands for older children are primarily at later stages, particularly during responding (Manis et al. 1980). Thus, direct tests of the attention-demand hypothesis could be made by assessing the cognitive effort of skilled and unskilled readers during the course of processing linguistic information, either at various stages of processing (e.g, encoding, rehearsal, responding) or at different levels of processing (e.g., sensory versus semantic).

A second major emphasis in studies of attention and reading concerns the notion that poor readers or reading-disabled children experience difficulties in selective attention (Douglas & Peters, 1979; Ross, 1976). Either they fail to attend to relevant cues or they are more readily distracted by irrelevant cues (Ross, 1976). But studies supporting the hypothesis of a relationship (e.g., Denny, 1974; Hallahan, Kaufman, & Ball, 1974; Keogh & Donlen, 1972; Mondani & Tutko, 1969) are, in many instances, contradicted by those that do not (e.g., Pelham, 1979; Pelham & Ross, 1977).

Evidence in favor of a relationship is outstanding from an applied perspective, as many teachers would attest (see Kinsbourne & Caplan, 1979). In fact, teacher perceptions have been well substantiated by several observational studies documenting the apparent "distractability" of exceptional learners (Krupski, 1980). Research of this kind, however, provides only indirect evidence to any hypotheses regarding attentional deficits. Teachers, and other observers, clearly are aware that some children do not conform to classroom demands but whether they cannot attend is another question. What teachers call selective attention may also refer to quite different attentional phenomena, such as arousal, vigilance, or concentration or the problem may not be one of attention at all. Individual differences in motivation (Kinsbourne & Caplan, 1979) and cognitive style (Zelniker & Jeffrey, 1978) may be attributed to an attentional deficit.

A second major source of evidence in favor of a relationship has been based upon the performance outcomes of proficient and poor readers on a central-incidental learning task (Hagan & Hale, 1973; Hagen, 1967; Hallahan et al. 1974). The task requires subjects to recall the serial position of cards displaying two line drawings, such as an animal and a household object. In sequential trials displaying three to six cards, subjects must recall the position of a particular card after each trial by attending to one of the picture categories. How well the spatial

locations are remembered provides a measure of central recall. Subjects are later asked to match the irrelevant pictures with the central items. The number of correct pairings provides a measure of incidental learning.

The results of several studies of this type have shown that poor readers and low achievers obtain significantly lower central scores, and either higher or equivalent incidental scores, relative to their controls (Hagan & Hale, 1973; Hallahan et al. 1974). These findings were taken as evidence in support of the hypothesis that learning disabled children suffer from a deficit in selective attention (Hallahan, 1975). Either they fail to focus attention or they are more distractible.

Similar group differences on the central-incidental tasks have since been attributed to a procedural artifact (Pelham & Ross, 1977). Since children who made errors appeared to scan the entire array of cards during the recall period, the incidental learning score may have represented a cumulative learning effect and not simply the result of initial exposure. Testing this hypothesis, Pelham and Ross manipulated exposure times to find that incidental learning did depend on the length of this period.

A study with more rigorous procedural controls was subsequently undertaken by Pelham (1979). Here, second, fourth, and sixth grade proficient and poor readers were compared on four tasks where developmental improvement in performance had been interpreted as improved selective

efficiency. These included a visual central-incidental task, an auditory central-incidental task (cf. Hallahan et al. 1974), a speeded classification task (cf. Strutt, Anderson, & Well, 1975) and a dichotic listening task (cf. Treisman & Riley, 1969). Overall, the results were mixed but were taken largely to mean that poor readers did not differ from their control counterparts. There were no group differences on the visual central-incidental task although deficient readers performed more poorly on the central part of the auditory central-incidental task. However, since list length and stimulus position influenced the central score - variables known to affect memory performance - Pelham argued that central recall differences reflected variations in mnemonic skills and not selective attention. Group differences on speeded classification, a choice RT task in which the amount of irrelevant visual information is varied, were also not significant although poor readers processed information more slowly. Similarly, the effect of distraction on the children's ability to shadow or repeat dichotically presented digits was negligible.

Conflicting evidence also can be found in other studies assessing distractibililty for information presented both auditorally and visually. On the one hand, there is some evidence that learning disabled children show a preference for the auditory modality (Senf, 1969; Senf & Freundl, 1971), or they are otherwise more distracted by auditory stimuli (Lasky & Tobin, 1973). In the Senf paradigm, for

example, subjects are asked to recall pairs of bisensory stimuli, where each pair consists of the simultaneous presentation of an auditory and visual stimulus. Three types of recall are then tested, including free recall, modality recall, or pair recall. In the free recall situation, learning disabled children tend to recall a greater proportion of auditory stimuli although they are less proficient in the other recall modes (Senf & Freundl, 1971). From these findings, Senf and Freundl suggested that the "... retarded reader is less able to exclude irrelevant stimuli (auditory distraction) or is stimulus bound by aural input (auditory dominance) (p. 105)". In contrast, Nobre and Nobre (1975) indicated that irrelevant stimuli involving competing verbal or nonverbal auditory information have no differential effects on auditory discrimination. In other studies, simple reaction time was found to be adversely affected by loud noise (Dykman, Ackerman, Clements, & Peters, 1971) but Lasky and Tobin (1973) found that only linguistic competing messages, and not white noise, distracted poor readers on a variety of tasks involving verbal or written responses to auditory or written instructions. In the visual modality, Santostefano, Rutledge, and Randall (1965) found reading disabled children less able to name colors of pictures and fruit when contradictory colors were used but Alwitt (1966) did not find the task of naming colored pictures to be negatively influenced by the use of inappropriate colors.

It should be noted that among studies employing recall as a dependent measure there is a potential confounding of attention and memory. Poor recall performance may result from faults in maintenance or retrieval mechanisms, and not selective efficiency. Findings that learning disabled children develop efficient mnemonic strategies more slowly, as measured by central recall (Tarver, Hallahan, Kauffman, & Ball, 1976; Torgesen & Goldman, 1977), supports this contention.

This same conclusion was advanced by Pelham (1979) when he argued that recall performance, and not selective attention, discriminated good and poor readers. But by the same token that recall differences cannot be said to support an attention deficit hypothesis, a failure to find such differences cannot be taken to mean that poor readers do not experience attentional problems. Recall measures may be simply inadequate to the task of determining an attention deficit.

The apparent inability of young readers to ignore irrelevant sources of information (Lehman, 1972; Samuels, 1967) formed the basis for others to test whether poor readers are more distracted by irrelevent material introduced in text (Singer, Samuels, & Spiroff, 1973; Willows, 1974; Willows & MacKinnon, 1973). Samuels' studies on the effect of pictures on the asquisition of reading responses showed that poor readers learned more words in the absence of pictures. While it can be said that poor and

proficient readers deployed attention in different ways, their conclusion that poor readers were distracted is open to question. A reasonable argument could be made that attending to the irrelevant cues was, in fact, an adaptive strategy. Poor readers, less able to extract the necessary information from the relevant source because they are poor readers, might well search other sources for needed contextual information. What was deemed irrelevant by the experimenters may not have been perceived as such by the children.

Willows (1974) and Willows and MacKinnon (1973) studied the reading performance of skilled and unskilled readers in a "reading-between-the-lines" task. In the Willows (1974) study, poor and good readers were required to read a passage of text printed in black that had distracting words printed in red inserted between the lines. The most interesting finding here was that good readers made more intrusion errors in a subsequent comprehension test; that is, more of the distractor words were given as answers. One possible explanation of this result is that since good readers read more efficiently, a greater expenditure of capacity or more processing time could be allocated to other sources of information. In any event, it would appear that poor readers were not distracted by the irrelevant information.

It would seem that few conclusions can be drawn regarding the selective attention deficit hypothesis. The complexities of the problem are outstanding, and at times,

they seem to undermine every attempt to elucidate their nature. Overall, the evidence for a selective attention deficit is equivocal primarily because supportive data, where it exists, is often confounded by the sensitivity of the dependent measures to processes other than attention. Fortunately, however, even studies apparently having failed to adequately test the hypothesis do provide some direction towards a possible resolution.

Measures of selective attention must be closely linked to the temporal sequence of events where attentional processes are presumed to be operative in order to avoid, or at least minimize, effects due to differences in other processes or abilities. Likely differences in mnemonic skills (e.g., Pelham, 1979) and conceptual thinking or problem-solving strategy (Singer et al. 1973) are two important variables to be controlled.

Secondly, the tasks themselves should be as free as possible from bias, whereby the particular mnemonic or problem-solving strategies of one group are not favored more than the strategies of another group, either by difference or degree. In other words, the tasks used should be relatively insensitive to variations in the proficiency level of good and poor readers with respect to processes other than attention (Douglas & Peters, 1979). As difficult to achieve as this may be, some tasks, more than others, would seem to satisfy this criterion. For example, the selective listening task of Johnston and Heinz (1978) may be

more appropriate than the central-incidental learning task since performance on the latter task has proved to be influenced strongly by mnemonic skill.

Another complication is introduced by the possibility that poor and proficient readers may demonstrate attentional differences with some materials and not others. Attentional effects were observed in a simple reaction time task (Dykman et al. 1971) but not when subjects shadowed dichotically presented digits (Pelham, 1979). Aside from any concerns about the validity of these findings, it will be important to delineate the conditions where attentional processes are important.

The approach recently taken by Johnston and Heinz (1978) to study attentional processes in adults seems particularly relevant to the problems of studying attentional differences between poor and good readers; in selective efficiency and the expenditure of processing capacity. Unlike many approaches, this approach originates from a set of theoretical propositions that may facilitate interpretation of empirical findings. The study of different modes of attention (i.e., sensory and semantic) permits a more refined analysis of the task conditions where attention effects may be observed. Also, the dependent measures appear to satisfy more adequately some of the criteria discussed earlier. Secondary RT to a simple probe stimuli, as an index of capacity, is measured coincidentally with the temporal deployment of attention. Similarly, selective efficiency, as

measured by target detection accuracy for the relevent inputs, also traces the immediate events without requiring inference from some other delayed outcome measure (cf. Pelham, 1979).

In view of these considerations, it is suggested that the question of a relationship between selective attention and reading difficulties can be addressed within this framework. Skilled and unskilled readers can be compared on the amount of effort expended and their efficiency when provided either sensory or semantic cues. Performance with two types of cues will suggest whether apparent deficiences are general or specific to a particular mode of processing. In sum, this approach permits a more refined analysis of the process of selective attention; determining what components, if any, may be related to reading skill.

Proposed Studies of Attention and Levels of Processing

The purpose of the present series of studies is to further examine the relationship between attention and levels of processing. The aspects of attention that are of particular interest include; cognitive effort, as measured by secondary probe RT and phasic HR change; breadth of attention, as measured by incidental learning of nontarget items; and selective efficiency, as measured by target detection accuracy. The two levels of processing under study include both sensory and semantic modes.

In each study, the divided attention procedure of Johnston and Heinz (1978) was used. The basic task required

subjects to divide their attention between two sources of input, or focus attention on one source to the exclusion of another, and to detect specified target words embedded within a list of nontargets that is presented from one source. This procedure was employed since it could be readily modified or adapted to meet the requirements of each particular study. Use of the same task in each case also would permit an assessment of the consistency of the data generated.

Study one examined the hypothesis that breadth of attention or sensitivity to nontarget inputs increases at "deeper" levels of processing (Johnston & Heinz, 1978). That more nontarget information reaches conscious awareness in a semantic mode than a sensory mode was supported by evidence that selective efficiency decreases and cognitive effort expenditure increases more in a semantic mode when two sources of input are presented or nontarget density is increased. However, these results provide only indirect support for the breadth hypothesis since levels of processing differences in cognitive effort and selective efficiency may be attributed to other factors. Since semantic encoding may require more effort irrespective of nontarget density, increases in density may compound the effort demands made upon the limited capacity system when it is engaged in semantic processing. With less residual capacity more errors in selection may occur (Eysenck & Eysenck, 1979). Also, increasing the number of inputs or

sources of information may produce a more difficult, and therefore, a more effortful task when a semantic level of processing is required since the inputs may be less discriminable.

The breadth hypothesis was tested more directly in study one by examining the effect of level of processing and nontarget density upon recognition memory performance in two selective attention procedures. In the first procedure, subjects were required to select designated target words from nontargets when the words were presented singly or in word pairs. Presenting two words simultaneously increases nontarget density and requires that subjects divide their attention between the two. According to the breadth hypothesis, recognition memory for nontargets should be proportionately greater when targets are selected on the bases of a semantic cue, and when nontarget density is increased.

The second procedure required focused attention or the selection of targets from a word list emanating from one source while ignoring a second list presented simultaneously from another source. If breadth of attention or sensitivity to nontarget inputs differentially increases in a semantic mode, then word recognition of items from the unattended or ignored source of input should be greater in the semantic mode.

Study two was designed to assess the expenditure of processing capacity associated with sensory and semantic

processing in a selective listening task using phasic HR change. In particular, the magnitude of HR acceleration was studied in order to further assess the hypothesis that cognitive effort increases with depth of processing (Craik, 1973). Such an approach was considered valuable for two related reasons. First, HR might serve as an independent index of depth of processing to the extent that HR discriminates between the sensory and semantic levels of processing on the basis of their hypothesized effort demands. Based on previous research (Dennis & Mulcahy, 1980; Shangi et al. 1978), the magnitude of HR acceleration occurring during semantic processing should exceed that found during sensory processing.

The second reason for studying HR concerns some potential problems with the secondary probe RT measure of effort. Although it is the only measure receiving empirical support there is a potential problem of specific interference effects between the secondary and primary task (Duncan, 1980). But HR could not interfere with the primary task since it does not require information processing. Thus, any confounds are effectively eliminated, and to the extent HR and secondary RT results agree, the latter behavioral measure would be validated further.

In addition, the hypothesized flexibility of attention was assessed in study two by recording HR when both sensory and semantic target selection cues were available. Johnston and Heinz (978) hypothesized that when both cues are

available subjects will adopt a sensory mode of processing either because it requires less effort or selective efficiency is greater. However, other evidence was presented to suggest that the level of processing engaged in a task is not absolute. Even when sensory processing is required some degree of semantic analysis also occurs (Nelson et al. 1979). A further empirical test of these alternative views was made by comparing HR patterns when subjects were provided either sensory or semantic cues individually or together. How well the HR pattern produced in the combined cue condition approximates the patterns in the single cue conditions would permit an assessment of each position.

Study three determined whether poor, average, or proficient readers differed in selective efficiency and cognitive effort expenditure as a function of level of processing and the presence or absence of a competing distractor. This study was designed to address several issues. First, the hypothesis that effort increases with depth of processing would be tested by using a secondary RT measure of cognitive effort in a selective listening task. This study would represent a partial replication of the work by Johnston and Heinz (1978), with additional attempts to control for some potentially confounding factors. An attempt was made to ensure that the semantic targets were clearly discriminable, and that the proportion of targets to nontargets were comparable between the sensory and semantic conditions.

Second, the measurement of both cognitive effort and selective efficiency would permit an assessment of the relationship between these two dependent variables. Presumably, effort and efficiency should be positively related.

Third, the distractability hypothesis was assessed in terms of the effect of a verbal distractor upon the selective efficiency and effort expenditure of each reading group. As was discussed previously, the results of distractability studies are difficult to interpret partly because differences between skilled and unskilled readers on various outcome measures, such as incidental or central recall, may be attributed to other aspects of information processing, such as mnemonic skill. In contrast, the selective attention procedure and the process measures of cognitive effort and selective efficiency were judged to be more appropriate to the task of determining an attentional deficit.

Finally, the notion that poor readers deploy their attentional resources inefficiently (Curtis, 1980) could be assessed directly by comparing the cognitive effort expenditures of skilled and unskilled readers. This work was extended by examining at what level of processing the skills of poor readers may deviate from the pattern shown by average or proficient readers.

III. DEFINITIONS, HYPOTHESES AND RATIONALE

Definitions

Breadth of Attention - refers to ",,, sensitivity to nontarget density" (Johnston & Heinz, 1978, p. 433) or awareness of concurrent inputs. Breadth is operationally defined in the present study as percentage recognition of nontarget items.

Cognitive Effort - refers to expended processing capacity, operationally defined behaviorally as reaction time to secondary probe stimuli, and physiologically as the magnitude of accelerative heart rate change.

Depth of Processing - refers to the "... degree of semantic or cognitive analysis" carried out in the encoding stage (Craik & Lockhart, 1972), where a semantic level of processing is "deeper" than a sensory level of processing.

Information Processing - refers to the manner in which individuals achieve, retain, and transform knowledge (Hall, 1980).

Levels of Processing - refers to "... a hierarchy of levels or stages of analysis running from the early analysis of physical features to later, more complex analyses of semantic features" (Craik, 1973, p. 48).

Processing Capacity - refers to ",,, the limited pool of energy, resources, or fuel by which some cognitive operations or processes are mobilized and maintained" (Johnston & Heinz, 1978, p. 422). The terms "cognitive

effort" and "expended processing capacity" are used synonymously.

Selective Efficiency - refers to the degree to which targets or relevant inputs are accurately selected from nontargets or irrelevant inputs, operationally defined as percentage errors in target detection, and consisting of either omissions (i.e., failure to detect a target) or intrusions (i.e., mistaking a nontarget for a target item).

Study One

Study one addressed the hypothesis that breadth of attention or sensitivity to nontarget inputs, increases from sensory to semantic modes of processing. Supportive evidence has been derived from observations that increasing the amount of nontarget information presented per unit time in a divided attention task differentially effects the amount of capacity consumed by selection, with increasing density more greatly effecting semantic selection (Johnston & Heinz, 1978). These results would suggest that, in the same instances of increased sensitivity, greater incidental learning of nontargets would also occur. Therefore, a greater proportion of nontarget items should be remembered following deeper levels of processing.

Study one consisted of two parts (A and B) in which two procedures were utilized to examine whether attending to sensory or semantic cues, in the context of a listening task, produces variations in incidental learning. The first

procedure (Part A) required subjects to divide attention between inputs in search of target items. The second procedure (Part B), utilized in a separate study, required subjects to focus attention on one source while ignoring another. In this instance, greater breadth of attention in semantic processing should be reflected by higher recognition scores for those items emanating from the unattended source. Hypotheses 1a and 1b below pertain to Part A. Hypothesis 1c pertains to Part B.

Hypothesis 1a

An interaction between type of cue (sensory versus semantic) and nontarget density (one versus two lists) is expected. Significant increases in incidental learning, as measured by recognition, will result as nontarget density is increased on semantic trials. Little or no effect is expected on sensory trials.

Hypothesis 1b

Recognition scores will be greater on semantic than sensory trials, regardless of nontarget density, for the divided attention paradigm.

Hypothesis 1c

Recognition memory for nontarget items from the unattended source will be greater in the semantic condition as compared to the sensory condition.

Study Two

Study two addressed two further hypotheses in multimode theory. The first asserts that a semantic mode of processing

will consume greater capacity. Second, multimode theory would predict that when both sensory and semantic modes of attention are available to select the inputs, processing will proceed only at the sensory level since it requires less capacity. This finding would be obtained to the degree that the selection process is energy efficient and capable of ignoring the semantic characteristics of the inputs.

In terms of physiological responses, the magnitude of heart rate acceleration should be greater for semantic than sensory cues. When the target stimulus can be selected on the basis of either its sensory or semantic qualities, then sensory selection should prevail. To the degree that the magnitude of change to sensory cues alone, and sensory plus semantic cues are equivalent, this hypothesis would be supported. Considering both hypotheses together, the magnitude of HR change should conform to the relationship between conditions where HR acceleration in a sensory mode of selection = a sensory plus semantic mode < a semantic mode alone. In other words, the magnitude of acceleration in the combined cue condition should equal that in the sensory cue condition but be less than that shown in the semantic cue condition.

A secondary consideration concerns the magnitude of acceleration to target items versus nontarget items. Johnston and Heinz (1978) suggested that listening to, rather than for, targets requires greater capacity. This result might be anticipated if an identified target is

further elaborated during encoding or subjected to a validation procedure. If so, then acceleration is expected to be larger to targets than nontargets. A similar assumption was made by Schulman (1974) to explain differences in recall between a "yes" response and a "no" response.

As HR is measured within a RT paradigm, response latencies associated with each type of selection task will also be assessed. No differences are expected since the delay between the onset of the task and the response signal appears sufficiently long to negate RT effects (cf. Dennis & Mulcahy, 1980). It is uncertain, however, whether target RT will differ from nontarget RT. The previous HR hypothesis would suggest longer RT's for targets but this effect also may be negated by the foreperiod duration.

Hypothesis 2a

It is hypothesized that HR foreperiod acceleration on semantic trials will exceed those on sensory trials. When both a sensory and semantic cue are available, HR acceleration is expected to approximate the acceleration associated with sensory selection alone.

Hypothesis 2b

The magnitude of the accelerative change will be greater for targets than nontargets.

Hypothesis 2c

Response latencies between conditions employing sensory, semantic, and sensory-semantic cues are

expected to be nonsignificant.

Hypothesis 2d

Recognition memory will be greater on semantic than sensory trials. Recognition following sensory-semantic trials should equal the memory performance following sensory trials.

Study Three

Study three attempts to assess whether the involvement of attention to an auditory selection task differs between skilled and unskilled readers under four selective attention conditions. Poor, average, and proficient readers are compared on the amount of cognitive effort expended, and their selective efficiency, when provided either sensory or semantic cues in the presence or absence of an auditory distractor. These stimulus conditions are designed to simulate the selective attention demands which might be experienced in a classroom.

This exploratory study attempted to answer several research questions regarding the relationship of attention to reading. No particular hypotheses are advanced in this regard, except where the outcomes of both skilled and unskilled readers can be predicted from multimode theory (Johnston & Heinz, 1978) or the attention demand hypothesis (Perfetti & Lesgold, 1978).

Research Questions and Hypotheses

Question 1

Does the presence of a verbal distractor differentially influence the capacity expenditure of each group using a sensory or semantic cue?

Question 2

Does the presence of a verbal distractor differentially influence the selective efficiency of each group using a sensory or semantic cue?

Question 3

Does proficiency in reading covary with the amount of effort expended on selective attention when readers are provided with either a sensory or semantic cue?

Question 4

Does proficiency in reading covary with selective efficiency, i.e., the ability to select relevant from irrelevant inputs, as a function of the availability of sensory or semantic cues?

Hypothesis 3a

It is hypothesized that, for all students, greater effort and lessened efficiency will occur in the presence of a verbal distractor.

Hypothesis 3b

It is hypothesized that, for all students, greater selective efficiency and the consumption of less capacity will result when a sensory cue is available. The converse is predicted when the situation demands a semantic mode of processing.

Hypothesis 3c

It is hypothesized that cognitive effort expended by poor readers in the sensory mode will exceed that of average and proficient readers. This hypothesis is based on the assumption that poor readers are less efficient information processors.

Hypothesis 3d

It is hypothesized that selective efficiency in the semantic mode will be less for poor readers than average or proficient readers. This result is expected if poor readers expend more capacity in the initial stages of processing, thereby restricting available capacity for additional cognitive operations required in the selection of targets from nontargets.

IV. STUDY ONE

Study one consists of two parts. Part A examined the effect of level of processing (sensory versus semantic), and nontarget density (one versus two lists) upon breadth of attention as measured by incidental recognition in a divided attention paradigm. The two list conditions (sensory and semantic) of Part A were replicated in Part B with different subjects with the exception that a focused attention paradigm was used.

METHOD

Experimental Paradigm and Design

Part A

A divided attention paradigm, fashioned after Johnston and Heinz (1978), required subjects to listen for, detect, and indicate the presence of specified target words embedded within a list of nontarget items. Four listening conditions, involving one list versus two lists presented binaurally, and the use of sensory versus semantic cues to detect targets, were compared in a 2X2 factorial design. Targets and nontargets were distinguished by either a sensory cue (male or female voice) or semantic cue (word category). The same number of targets appeared in one list and two list conditions. Only nontarget density was increased in the two list conditions.

Part B

The two list conditions (high nontarget density) of Part A were replicated except that a focused attention

procedure was used. Subjects were required to listen to one list containing the target items and ignore the source of the second list, as compared to listening to both lists simultaneously as was the case in Part A. This procedure was implemented to ensure that differences between sensory and semantic modes of processing were not simply a function of differences in depth of processing. The breadth hypothesis would require that subjects be more sensitive to nontarget inputs in a semantic mode even if the source of nontarget input was unattended.

Subjects

Sixty-two female volunteers, with a mean age of 20.2 years (s.d.=1.1), were recruited from undergraduate educational psychology courses. Ten subjects were randomly assigned to each of the four conditions in Part A, with two groups of eleven Ss randomly assigned to the sensory and semantic conditions in Part B.

Apparatus and Stimuli

Two lists of 26 words were constructed randomly from a pool of 52 words drawn from the Rosch (1975) norms. List one contained 24 nontarget words represented equally by four taxonomic categories; furniture, clothing, vegetables, and tools. Those words selected were judged by Rosch (1975) to be the most representative of their respective category. The remaining two items, designated as target words, were arbitrarily selected from the clothing category for use in the sensory condition.

The words 'car' and 'truck' were substituted as target words in the semantic condition. These words were selected since they were found by Rosch to be more representative of their taxonomic category than words in any other category. This procedure would help ensure that the semantic target words were discriminable from the nontarget items.

The position of the two target words in the list of 24 nontargets was determined at random by drawing two numbers from a pool of 26 numbers. All other nontarget words were then randomly assigned to the remaining positions in the list. Thus, the composition of list one was exactly the same for the sensory and semantic conditions except for the two target words.

The second list of 26 words was composed entirely of nontarget items selected at random from the four taxonomic categories comprising the original pool of 52 words. The position of each word in this list was determined by assigning each word a number that was drawn randomly from a pool of 26 numbers. The only constraint was that a word could not be phonetically similar to the word located in the same position in list one. Otherwise, two phonetically similar words presented simultaneously in the two list conditions would be less discriminable. Two short 10 item lists, with one target word presented in a manner consistent with each experimental condition, were also constructed for the purpose of practice trials. Subjects in each condition were presented with only two trials, including one practice

trial and one experimental trial.

Each word list was studio recorded on a Sony TC-630 at the rate of one word every two seconds, with the second list synchronized with the first list for use in two list (high nontarget density) conditions. Polygraph tracings showed that word onset times were within 100 msec. on two list conditions. Word lists are shown in Appendix A.

All words were spoken in one of four male voices with the exception of the two target words used in sensory trials. These items were spoken in one of two female voices. The sensory task, then, would require Ss to discriminate two female voices from four male voices, whereas the semantic task involved selecting the two words from the category vehicles from the remaining four taxonomic categories.

All Ss were tested individually in a sound-attenuated chamber which contained a reclining chair, target detection apparatus, and two audio speakers. The recorder and all control apparati were located in an adjacent room. The audio speakers were located approximately 1.5 m. in front of the Ss. Speakers were separated by 1 m.

Dependent Measure

Percentage Recognition: This measure was calculated as the number of correctly recognized nontarget words, minus the number of intrusion errors; i.e., words not contained in the set of nontargets. Two recognition lists were used. Subjects participating in the one list conditions of Part A were given a recognition list containing the 24 nontarget

items of list one randomly interspersed between an equal number of distractor items selected at random from the remaining words listed under the same taxonomic categories in the Rosch (1975) norms. The recognition list used following two list conditions studied in Part A contained the nontarget words from both lists (50 in total) plus an equal number of distractor items. This same recognition list was divided into two sections for the purpose of measuring recognition of items from the "attended" and "unattended" source in Part B of this study. Section one contained the nontarget words from the "unattended" source (i.e., list two) while section two contained items from the "attended" source (i.e., list one). Percentage recognition of nontarget words provided an index of breadth of attention.

Procedure

Subjects were randomly assigned to each experimental condition depending upon their order of arrival to the laboratory. Each subject was seated in the experimental chamber and then explained the use of the "yes-no" button press apparatus; pressing "yes" if they heard a target word and "no" otherwise. This apparatus was positioned on their preferred side and their response was recorded manually from a corresponding "yes-no" light signal device located in the control room.

All Ss were informed of the four semantic word categories, the number and sex of the voices in which the words were spoken, and the target selection criteria prior

to the practice trial and again, before the experimental trial. Subjects participating in the semantic conditions were requested to listen for words that represented vehicles, such as car and truck. No subject was informed of the list length or the number of target words since this information would have precluded further nontarget processing when they realized they had detected all available target words.

In Part A, subjects were requested to listen to either a single list (low nontarget density) or two lists (high nontarget density) which they would hear simultaneously, as if to listen to two people talking at the same time. In Part B, they were requested to listen to the words emanating from only one channel and ignore the other. The source of the attended channel was determined as either the left or right speaker depending upon their preferred side for locating the "yes-no" response apparatus. List one and list two were presented in the "attended" and "unattended" channel, respectively.

Immediately following the experimental trial all subjects were provided the appropriate recognition list and asked to circle any word they had heard. Thereafter, the purpose of the experiment was explained in a debriefing session.

RESULTS

Part A

The percentage recognition data were analyzed in terms of level of analysis and nontarget density (Table 1). Consistent with levels of analysis theory, and as predicted in Hypothesis 1b, semantic recognition memory significantly exceeded sensory recognition memory ($F_{1,36} = 11.8$, $p<.01$). Average recognition scores for the semantic and sensory conditions, collapsed across nontarget density conditions, were 42.6% and 26.5%, respectively.

The main effect associated with nontarget density ($F_{1,31} = 52.4$, $p<.001$) showed that increasing the number of nontargets in the two list conditions reduced percentage recognition. But contrary to the hypothesized interaction, this effect was similar for both sensory and semantic levels of analysis (upper panel Figure 1). The only indication of a possible differential effect was the percentage decrease in recognition. Increasing density resulted in a 12% greater decrease for the sensory condition as compared to the semantic condition. This was, however, not found to be a reliable difference.

Part B

Analysis of the percentage recognition data consisted of a 2 (levels) X 2 (channels) analysis of variance with repeated measures on the second factor. The summary analysis is given in Table 2 and the percentage recognition scores are shown in the lower panel of Figure 1.

As might be expected in this type of paradigm, recognition performance was vastly superior for items

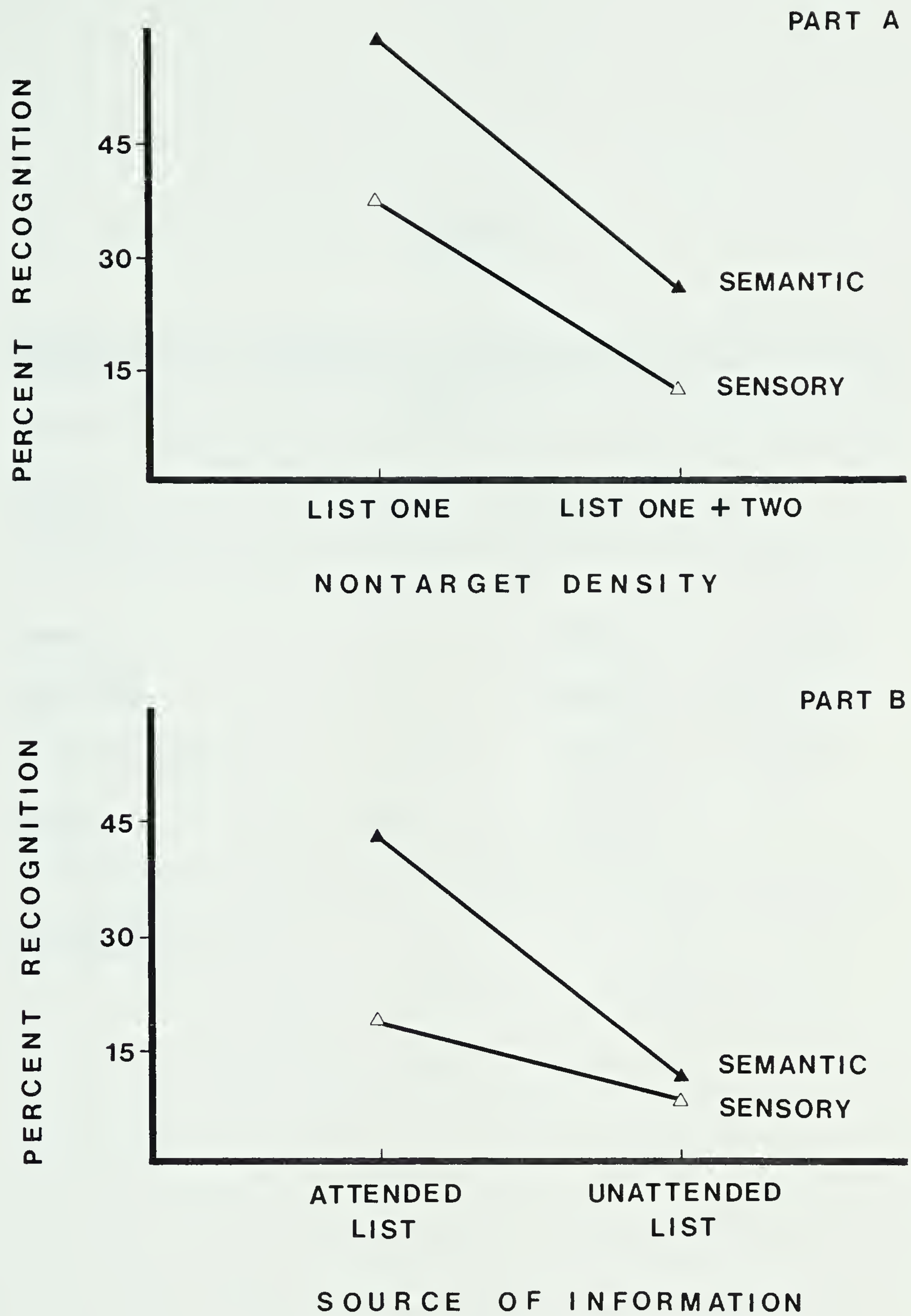

Figure 1. Percentage recognition of nontarget items following sensory and semantic processing in a divided attention task (Part A) and a focused attention task (Part B).

Table 1

Analysis of Variance of Recognition Memory Data
:Part A

Source	df	MS	F
Levels	1	1787.6	11.83*
Density	1	7918.6	52.38**
Interaction	1	337.5	2.23
Error	36	151.2	

* $p<.01$
** $p<.001$

Table 2

Analysis of Variance of Recognition Memory Data
:Part B

Source	df	MS	F
Between			
Levels	1	1999.35	18.33**
Error	20	109.06	
Within			
Density	1	4990.58	52.60**
Interaction	1	1019.52	10.80*
Error	20	94.84	

* p<.01
** p<.001

emanating from the attended channel, as compared to the unattended channel ($F_{1,20} = 52.6$, $p<.001$). More importantly, the analysis showed a large effect of processing depth ($F_{1,20} = 18.33$, $p<.001$) in which semantic processing produced a much higher level of recognition than did sensory processing. Recognition performance did, however, depend on whether the source was attended or unattended, as evidenced by the significant interaction ($F_{1,20} = 10.8$, $p<.01$) Scheffe' post hoc comparisons indicated that recognition for sensorially and semantically encoded words did not differ when they originated from the unattended source although all other possible contrasts were significant. These findings are consistent with the results of Part A that show superior memory performance but no evidence for greater breadth of processing following semantic analysis.

DISCUSSION

Overall, the results presented in Parts A and B fail to support the hypothesis advanced by Johnston and Heinz (1978) that breadth of attention increases with depth of processing. In Part A, recognition memory was influenced by depth of processing, as well as the density of nontarget information but these two factors did not interact. Each of these main effects is entirely consistent with what is known about their effect on memory performance. Recognition memory is generally superior subsequent to semantic analysis (e.g., Parkin, 1979), and because of upper limits in the amount of information that can be retained in this type of incidental

learning paradigm, percentage recognition will decrease as the memory set size increases (Corballis, Kirby & Miller, 1972).

In Part B, the main finding was that information retained from an unattended source during focused attention is quantitatively similar for both sensory and semantic modes of processing. Some information from the unattended source was extracted (see Figure 1) but conscious focusing of attention eliminated the input for both sensory and semantic encoding strategies to the point where they no longer differed.

The results of Part A and Part B clearly indicate that breadth of attention or sensitivity to nontarget items, either from an attended or unattended source, is not a sequelae specific to a semantic mode of information processing. Instead, the memorial superiority of semantic processing may be attributed to the greater depth of analysis that the words were analyzed.

The breadth hypothesis was originally supported with the findings that increasing nontarget density in a divided attention task increased cognitive effort (secondary RT) and decreased selective efficiency (%correct on target detection) more for a semantic than a sensory level of analysis (Johnston & Heinz, 1978). On the basis of this data, Johnston & Heinz suggested that;

> "...greater reliance on semantic cues may render the system more sensitive to nontarget inputs, if for no other reason than that semantic selection is less effective at keeping nontarget inputs out of consciousness" (p. 433).

The present study does not directly address the issue of selective efficiency since target items were identified equally well for both modes of processing but it does show that attention is no more captured by extraneous inputs in the semantic mode than in the sensory mode. What does require explanation is why increased nontarget density resulted in increased effort more for semantic analysis in the experiments of Johnston & Heinz (1978). Two points seem particularly relevant to this question. First, the procedure adopted by Johnston and Heinz required Ss to divide their attention between two competing sources of information; that is, words were presented simultaneously from two separate channels of a stereo system. Under these conditions, there is no extraneous information since Ss are forced to analyze nontarget words from all sources in order to discriminate between them. Since it can be much more difficult to discriminate words on the basis of their semantic features (Keele, 1973), increasing nontarget density would increase effort and lessen selective efficiency due to the more difficult discrimination problem.

Second, the number of items to be discriminated differed with each level of analysis. In their fifth

experiment, for example, words spoken in a female voice (targets) were to be discriminated from words spoken by a male (nontargets). A single semantic trial consisting of one list required identification of 2-4 target items from an array containing approximately 30 nontarget words drawn from eight semantic categories. Such a difference in effective set size may, in itself, be sufficient to produce marked differences in the effort required to process the information (cf. Dennis & Mulcahy, 1980) although when set size differences are less pronounced, cognitive effort will be greater for information subjected to a semantic level of analysis (Mulcahy & Dennis, Note 1; Eysenck & Eysenck, 1979). Presumably, greater effort is required because semantic analysis evokes more elaborative encoding of the word features (Craik, 1973).

Whether or not attention is captured by, or is sensitive to, nontarget sources of information will depend on a number of factors. Relevancy of the information to the individual (Corteen & Wood, 1972), characteristics of the stimuli, such as salience or intensity (Massaro, 1975), and the ability to sustain attention (Mackworth, 1969), are representative of some of the factors that have been identified.

The effort demands of the attended task may also influence breadth of attention. Tasks with minimal effort demands would leave sufficient residual capacity to analyze other sources of information input. High effort tasks, on

the other hand, would so fully occupy the resources of the information processing system that attention would be restricted to the attended task. The data in Part B support this notion in that the items retained from the unattended source, relative to the attended source, were significantly fewer in the semantic mode than in the sensory mode. Of course, switching from one source to another or one task to another could be accomplished but only at the expense of lessened processing efficiency for information originating from the primary attended source. This hypothesis is counter to the breadth hypothesis of Johnston & Heinz (1978) since greater breadth of attention should be attainable during sensory processing as more residual capacity could be allocated to other inputs. But here it is less a question of sensitivity to other information sources, and more a statement that the perceptual processing system is flexible in being able to selectively attend to one or more sources of information, as well as being able to shift from one mode of processing to another.

This study has considered the effects of depth of processing on breadth of attention. The next study to be presented examines the relationship between depth and cognitive effort, as measured by phasic heart rate changes.

V. STUDY TWO

The purpose of this study was two-fold. First, it was designed to assess the cognitive effort demands of sensory and semantic selective listening tasks by phasic heart rate changes. Second, the prediction that a sensory mode would be adopted given both sensory and semantic cues was tested by comparing HR patterns when the levels cues were provided singly or together. In addition, measurement of incidental recognition of items processed at each level of analysis would permit a partial replication of the two list conditions of study one, Part A.

METHOD

Experimental Paradigm and Design

The selective listening task of study one was modified to conform to a fixed foreperiod RT paradigm typically used to study phasic HR changes. The auditory task consisted of a simultaneous, binaural presentation of two words followed five seconds later by a tone signal requiring the subject to indicate, by a button press response, the presence or absence of a target word. Each of the 20 trials were separated by an interval of 10 secs. to permit a cardiac recovery period and second-by-second HR changes occuring during each trial were measured. Subjects participated in one of three conditions where target words could be distinguished from nontargets by a sensory cue (male vs female voice), a semantic cue (taxonomic category), or both a sensory and semantic cue. One-half of the trials in each

condition contained a target word.

Subjects

Thirty-nine male subjects recruited from the Departments of Psychology and Physical Education received course credit or $3.00 remuneration for their participation. Their mean age was 19.6; s.d.= 1.7. Subjects were randomly assigned to one of three experimental conditions depending upon their time of arrival.

Apparatus and Stimuli

Twenty word pairs (40 words) representing seven taxonomic categories were drawn from the Rosch (1975) norms. Five words were taken from each of the following six categories: clothing, tools, furniture, fruit, weapons, sports. Ten words were drawn from the category vehicles. Word pairs were drawn randomly and then randomly assigned a position from one to twenty. Pairs which were phonetically or semantically similar were redrawn to produce a new combination. Presentation of each word pair constituted one trial, and ten of the twenty trials contained a target item.

This set of 20 word pairs was used in each condition to ensure that variations in cognitive effort were due to the type of cue (sensory versus semantic) and not to word difficulty. Each condition did differ, however, in terms of available target selection cue. Targets on semantic trials consisted of ten vehicle names, such as car and bus. Vehicles was chosen as the taxonomic category since the words in this category were judged by Rosch (1975) to be

more representative of their category than words in any other category. One-half of the target items were spoken in one of two female voices, with all other words in the list of word pairs spoken in one of four male voices. Thus, the target selection cue was semantic category and not voice. Targets on sensory/semantic trials consisted of the same ten vehicle names except that all targets in these combined cue trials were spoken in one of two female voices. The nontarget words were spoken in one of four male voices. Therefore, sensory/semantic targets could be identified by both voice and taxonomic cues. Targets on sensory trials were five vehicle names and five items randomly selected from the other categories, all spoken in one of two female voices. The remaining items were spoken in a male voice. In this condition then, only voice would reliably differentiate target from nontarget items.

Word lists were studio recorded on a Sony TC-630 with each item of a word pair recorded simultaneously on separate channels. Word onset times were kept within 100 msecs. A 100 db tone, with a 500 msec. duration, was recorded 5 secs. following word onset. Audio levels for the word lists were approximately 80 db. Word lists are shown in Appendix B.

The response apparatus consisted of two microswitches, marked 'yes' and 'no', protruding from a metal box located on the subject's preferred side. The subject's response stopped a digital RT clock automatically activated in sequence with the reaction tone signal.

Heart rate was recorded by use of silver-silver chloride electrodes placed on the sternum and the third left rib, with a neutral ground on the left shoulder. The 12.7 mm electrodes were contacted with Beckman paste and secured by adhesive collars. Two channels of a Hewlett-Packard 1500 polygraph with an integrated cardiotachometer were used; one to measure heart rate and one to record the stimulus onset signals during each trial. Chart calibration was checked and adjusted, if necessary, prior to testing each subject. Paper speed was set at 5 mm./sec. Polygraph recordings of second-by-second heart rate changes were hand digitized for subsequent analyses. Interrater reliablility, calculated as percentage agreement between two raters on a random sample of four HR records, was 98.7%.

Subjects were tested individually in a sound-attenuated chamber containing a reclining chair, response apparatus, and two audio speakers. The speakers were situated approximately 1.5 m. in front of the Ss. Speakers were separated by 1 m. The recorder, RT clock/counter, polygraph, and all other apparati were located in an adjacent control room.

Dependent Measures

Reaction Time: Median response latencies of the "yes-no" button press were calculated for the targets and nontargets in each condition. Data from error trials, which averaged 4%, were excluded from the statistical analyses.

Percentage Recognition: The number of correctly recognized nontarget words, minus the number of intrusion errors; that is, words not contained in the set of nontargets, were calculated for each of the three conditions: sensory, semantic, and sensory/semantic. The recognition list contained only those words commonly used as nontargets in each of the three conditions, interspersed between an equal number of distractor items selected randomly from the remaining words listed under the same taxonomic categories from which the nontargets were drawn. Thus, the ten vehicle names and the five words used as targets in the sensory condition were eliminated. This procedure produced a set of 25 nontarget words common to each condition.

Cognitive Effort: A continuous sample of second-by-second HR beginning 2 sec. prior to word onset and ending 4 sec. following the response tone were measured. Each trial consisted of a 2 sec. preperiod, a 5 sec. foreperiod, and 4 sec. postperiod. The dependent measure was the difference scores produced by subtracting the average HR of the 2 sec. preperiod from the HR score measured at each subsequent second. Data from error trials were excluded. Heart rate changes for each subject were averaged over trials for the target and nontarget items of each condition.

Procedure

Subjects were explained the nature of the respective tasks, and all apparati, while electrode placements were

made. Subjects were instructed to listen to the word lists and indicate the presence of a target word by pressing the "yes" or "no" button as quickly as possible when they heard the respond tone that followed word onset by 5 sec. They were informed that the purpose of the study was to assess the relationship between behavioral RT responses and physiological HR responses. No mention was made of the recognition test to follow. Several minutes were then provided for Ss in the semantic or sensory/semantic condition to study and rehearse the list of target words. This rehearsal procedure was intended to ensure that Ss could identify the specific target words and thereby reduce uncertainty about the status of any single word as a target item since words may vary in how well they represent their particular taxonomic category (Rosch, 1975).

Subjects adjusted the chair to a comfortable reclining position in order to minimize unnecessary movements. Ten minutes of quiet preceeding the experiment permitted sufficient time for stabilization of tonic HR levels while the control apparati were adjusted and calibrated. Ten practice trials were given, followed by a brief review of the experiment and a call for any questions. Twenty experimental trials followed. Subjects were given the recognition list containing the nontarget items at the end of the session.

RESULTS

Reaction Time: Median response latencies to targets versus nontargets were compared for each levels condition in a 2 (word type) X 3 (levels) analysis of variance (Table 3). In accord with hypothesis 2c, response latencies were not statistically different. The mean RT, collapsed across all conditions, was .654 secs., s.d. = .02. This result was expected since the RT's indicate time required to react to the respond signal and not the time required to make a decision.

Recognition Memory: Percentage recognition, corrected for the number of false identifications, was compared for each of the three levels conditions: sensory, semantic, and combined sensory/semantic (Table 4). One-way analysis of variance indicated that recognition memory performance differed between conditions ($F_{2,36} = 7.47$, $p < .01$). Scheffe' post hoc pairwise contrasts showed that semantic recognition (33.1%) exceeded sensory recognition (13.5%) but scores for subjects in the combined condition (25.4%) were not reliably different from the other groups. Greater variability of scores in the combined cue condition suggested that Ss may have used mixed processing strategies. Subjects either processed the semantic content on some trials and not others or some subjects primarily adopted a sensory mode while others preferred a semantic mode. The latter possibility seems likely since memory scores in the sensory/semantic condition formed a bimodal distribution

Table 3

Analysis of Variance of Median Response Latencies

Source	df	ms	F
Between subj			
Levels	2	.015	.104
subj w grp	36	.149	
Within subj			
Word Type	1	.008	1.000
Levels X Type	2	.000	<1
Type X sub w grps	36	.008	

Table 4

Analysis of Variance of Percentage Recognition

Source	df	ms	F
Between			
Groups	2	1269.8	7.47*
Error	36	169.98	

*p< .01

where each mode corresponded to the modal points found in the unimodal distributions of the sensory and semantic conditions. These findings are contradictory to Hypothesis 2d, and the assertion by Johnston and Heinz (1978) that a sensory mode would be preferred because it requires less effort. This will be further amplified in the discussion section of this chapter.

Heart Rate: The data from trials where Ss made an error or pressed the "yes-no" decision button prior to the respond signal were excluded from the data analyses. Errors and anticipatory responses averaged 4.0% and 9.4% of the trials, respectively. Data from trials where HR exceeded prestimulus levels by 10 bpm during the accelerative phase also were excluded since these HR responses do not conform to the typical pattern shown in a fixed-foreperiod RT paradigm (cf. Shangi et al. 1978). These extreme accelerative responses, averaging 8.2% of the trials, appeared to occur when Ss did not clearly distinguish the word or when Ss were surprised or startled by word onset. These explanations were based on Ss self-report. The frequency of anticipatory response trials and extreme accelerative response trials were proportionately equivalent between the three groups.

Prestimulus HR differences between each levels condition where analyzed in a one-way analysis of variance. Since this analysis showed no significant differences (F 2,36 = .94), the HR data where then analyzed for sec-by-sec changes in a 2 (word type) X 3 (levels) X 10 (seconds)

analysis of variance. The second and third factors were repeated measures. As may be seen from Table 5, there was a significant main effect for seconds ($F_{9,324} = 3.56$, $p < .001$) and significant interactions involving levels X seconds ($F_{18,324} = 3.68$, $p < .001$) and levels X word type X seconds ($F_{18,324} = 1.71$, $p < .05$). The three-way interaction was further analyzed in a series of post hoc contrasts.

Heart rate to target words appeared to produce two distinctive patterns (Figure 2). Heart rate responses to the semantic and sensory/semantic tasks appeared to be equivalent except that the middle foreperiod acceleration was significantly greater for the sensory/semantic task beginning at second 6. The second distinctive pattern is shown in response to the sensory task. Acceleration began two seconds sooner and the increase in bpm is significantly higher at the 6 and 7 second mark. Heart rate during the postperiod, from seconds 7-10 inclusive, follows the same basic pattern in each condition although they differ in their level of elevation.

It was hypothesized that the magnitude of HR acceleration during the foreperiod, as a measure of cognitive effort, would be greatest for the semantic condition and equivalent between the sensory and sensory/semantic conditions. The results did not conform to this expectation since acceleration was greatest to the sensory level task. Furthermore, the observation that the HR

Table 5

Analysis of Variance of Heart Rate Scores

Source	df	ms	F
Between subj			
Levels	2	1.427	.11
subj w grp	36	12.795	
Within subj			
Word Type	1	1.169	.17
Level X Type	2	4.416	.64
Type X sub w grp	36	6.950	
Seconds	9	3.24	3.56**
Levels X Secs	18	3.349	3.68**
Secs X subj w grp	324	.91	
Type X Secs	9	.778	.98
Level X Type X Secs	18	1.358	1.71*
Type X Sec subj w grp	324	.795	

p<.05*
p<.001**

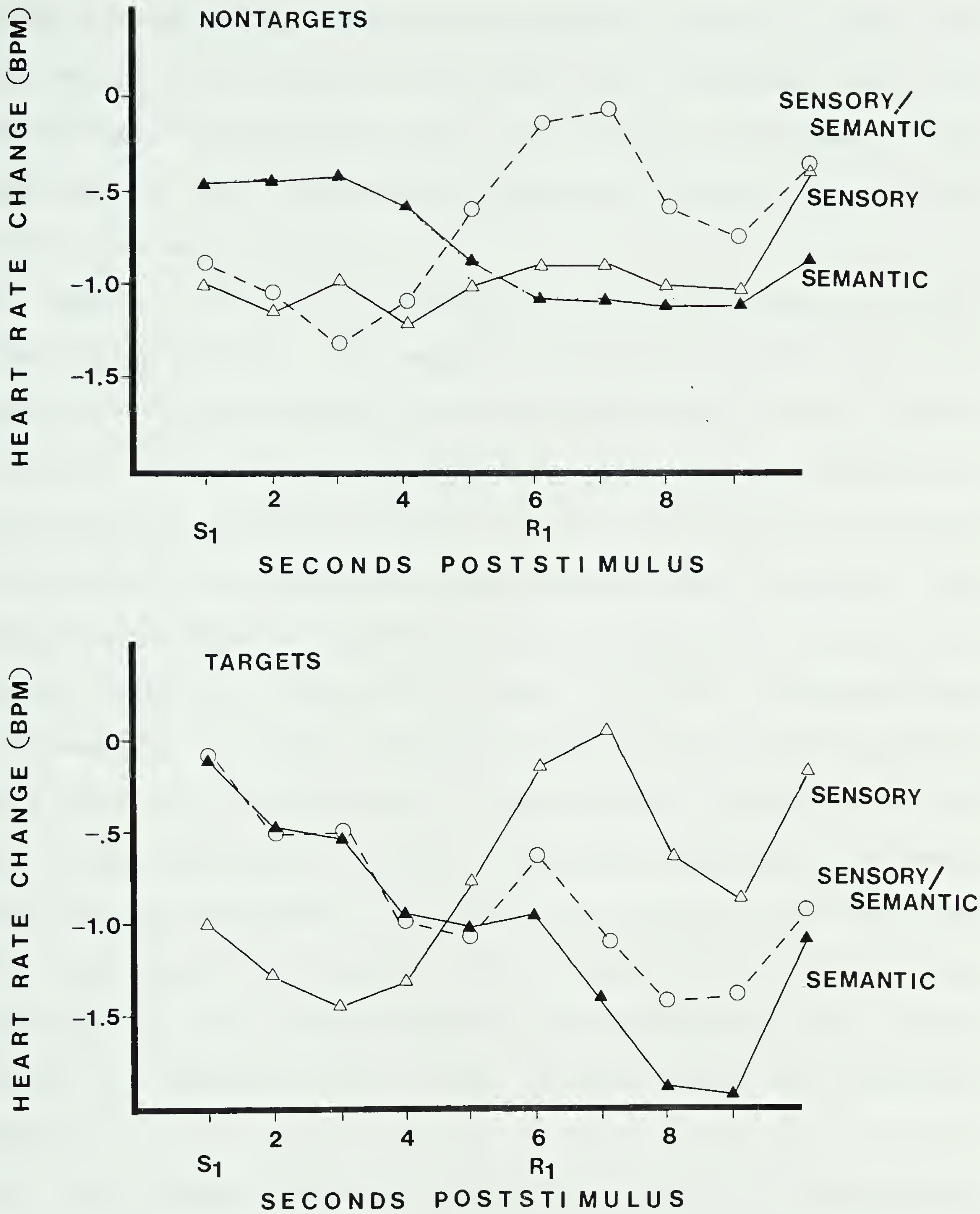

Figure 2. Mean second-by-second heart rate values for nontargets and targets given sensory, semantic, or sensory/semantic cues. (Each point represents the difference between the mean of the two prestimulus heart rate values and the heart rate values for each second. Points marked S1 and R1 indicate onset of the word pairs and reaction signal, respectively.)

pattern produced by the combined sensory/semantic task did not match the sensory HR pattern is in agreement with the percentage recognition data in failing to support the hypothesis that equivalent patterns between these two conditions would result.

Heart rate to nontarget words presents a more complicated picture. The semantic HR pattern shows only a significant deceleration with a plateau effect in the last 6 seconds. This pattern approximates the form produced in response to semantic targets except that both accelerative and decelerative components were greater for targets. The sensory nontarget HR pattern also corresponds to the sensory target pattern, showing a sharp initial deceleration followed by a slight, nonsignificant accelerative response until the final second when a significant acceleration to the baserate begins to occur. The major consistency between the sensory and semantic HR patterns is that the magnitude of accelerative change is greater to targets than nontargets. This finding supports the hypothesis that "yes" items or targets are further elaborated in the encoding process.

The sensory/semantic nontarget HR pattern represents a special case. Whereas the target HR pattern in the sensory/semantic condition approximated the target pattern of the semantic condition, the nontarget sensory/semantic pattern more closely parallels the sensory target pattern. Like the distinctive accelerative pattern in the sensory

target condition, HR acceleration in response to sensory/semantic nontargets significantly exceeds acceleration to nontargets in the other conditions. This data suggests that Ss tended to process sensory/semantic targets to a semantic level while restricting encoding of nontargets primarily to a sensory mode. This interpretation conflicts somewhat with the recognition data since it appeared that both modes were utilized in the processing of .

DISCUSSION

Superior semantic recognition shown in study two concurred with the results in study one, as well as the general finding in the majority of studies assessing word retention in a levels of analysis task (e.g., Parkin, 1979). Percentage recognition scores for sensory and semantic modes of processing were 13.5% and 33.1%, respectively. These results are comparable to the figures of 12.5% and 25.6% observed in the two list conditions of study one, Part A. What was further demonstrated in the percentage recognition results is that the level at which information is processed, given a choice between equally effective modes for decision making, is based on more than "cost" efficiency. Presumably, efficiency would be demonstrated if Ss adopted a sensory mode since this level of analysis may have required less cognitive effort. Individual differences appeared to play a significant role since some Ss appeared to choose a semantic mode in preference to the less effortful sensory mode. This

finding is in contradiction to the cost efficiency expectations of Johnston and Heinz (1978) but not in terms of the finding that adult Ss will extract semantic information from analyses of sensory features embedded within words (Nelson, Walling, & McEvoy, 1979). Another factor that may influence choice of processing modes is the relative difference in effort expenditure required. The difference between sensory and semantic levels in the Johnston and Heinz (1978) studies, as measured by secondary RT, were typically less than 50 msec. Since the tasks and procedures in this study were similar, the relative cost savings of 50 msec. of additional processing time may have been insufficient to induce Ss to meet the task requirements using a "shallower" depth of analysis.

The HR results presented a much more complicated picture than was originally conceived. On the basis of previous research (Dennis & Mulcahy, 1980; Shangi et al. 1978) it was anticipated that HR would follow a triphasic pattern during the foreperiod. This pattern consists of an initial deceleration to stimulus onset followed by a marked acceleration indicative of cognitive processing and then a final deceleration that reaches the nadir or lowest point at the time of a response. The HR hypotheses generated from this research concerned only the magnitude of accelerative change. Since the patterns shown in Figure 2 reflect complex differences it is apparant that corresponding only acceleration magnitude with the cognitive effort

characteristics of levels of analysis was too simplistic an interpretation for the procedures and tasks studied here.

Hypothesis 2a, in part, stated that HR acceleration on semantic trials would exceed that on sensory trials. This hypothesis assumed that HR would distinguish each processing mode on only one unidimensional characteristic; that is, the amount of cognitive effort required. When HR to targets was compared to HR to nontargets within the same level of processing for both the sensory and semantic modes, this result was observed. Acceleration was greater to target words in both cases, presumably because the target or "yes" items where further elaborated in the encoding process (Schulman, 1974). However, comparisons between the sensory and semantic levels cannot be interpreted in this unidimensional fashion. Accelerative and decelerative points during the foreperiod for sensory and semantic modes all began at different points in time, thereby suggesting qualitatively distinct processing strategies that may have varied on a number of dimensions. For example, HR deceleration is thought to index attention to external sources of incoming stimuli (Coles & Duncan-Johnson, 1975). Deceleration in the semantic mode did not reach its nadir until 2 secs. after the point of maximum deceleration in the sensory mode. The semantic task may have required a longer attentional set in order to decode the inputs. Differing degrees of word discriminability between the processing modes may have contributed to this effect.

The triphasic pattern described previously has been demonstrated in a levels of analysis task in one previous study (Shangi et al. 1978). The present study differed in at least two important ways that may have contributed to the qualitatively distinct HR patterns. First, a visual rather than an auditory presentation method was tested by Shangi et al. The current HR research literature does not specifically address the issue of input modality with studies equating levels tasks that vary only in method of input but evidence of differential effects in other information processing studies suggests this likelihood. For example, visual presentation of input may encourage a simultaneous processing strategy whereas an auditory presentation in serial fashion may require successive processing, although some auditory and visual memory tasks may both load on a successive factor (Das, Kirby, & Jarman, 1979). Determining HR differences between simultaneous versus successive strategies or other sources of potential difference between auditory and visual presentation methods cannot be readily assessed from the current field of research but a retrospective analysis of several studies suggests that such differences may be important. In a fixed-foreperiod paradigm, where the time intervals between stimuli onset are fixed rather than variable, and when repeated trials are presented, Ss will anticipate stimulus onset with a phasic HR change. Considering ten studies including the present one, five studies presenting visual stimuli in the form of

lights, words or digits showed anticipatory *decelerations* (Coles & Duncan-Johnson, 1975; Dennis & Mulcahy, 1980; Jennings & Hall, 1980; Krupski, 1975; Shangi et al. 1978). Three studies presenting auditory stimuli in the form of words or digits, including the present study, showed anticipatory *accelerations* (Kjellberg & Magnusson, 1979; Tursky et al. 1970). The remaining two studies showed anticipatory decelerations to an auditory presentation of tones and letters (Coles & Duncan-Johnson, 1977; Kjellberg & Magnusson, 1979). While these results are not perfectly consistent, observing anticipatory accelerative responses to various visual inputs with mixed effects in response to auditory material suggests the possible importance of factors such as stimulus presentation method.

A second source of difference between the present study and that of Shangi et al., (1978) concerns other procedural and task characteristics. The current study required Ss to discriminate word pairs presented binaurally where the decision of target detection took place during the foreperiod. Shangi et al. presented written questions on slides, such as "Does this word begin with the letter S", or "Does this word mean a type of vehicle", to induce sensory and semantic processing, respectively. The decision could not occur until receipt of the response word presented at the end of the foreperiod. Furthermore, the sensory-semantic distinction was between encoding a letter or series of letters and encoding for word meaning. The present study

compared HR for decisions based on voice quality (female vs male) versus word meaning. Any one of these task distinctions may have been sufficient to produce markedly distinct HR patterns.

Of course, it might be argued that the paradigm was inappropriate for the task of detecting levels differences in expended processing capacity. The capacity requirements of sensory and semantic *encoding* processes where expected to be maximal during the first second following word presentation, and since maximal HR acceleration typically occurs later with a 5 second foreperiod duration, accelerative change may lag behind the temporal sequence of processing events. Perhaps an analysis of HR change measured in 100 msec. units within the first 2 seconds of the foreperiod would be a more sensitive index of encoding effects.

What the present research does demonstrate is that sensory and semantic information processing strategies are qualitatively distinct, as suggested in the original formulations of levels of analysis (Craik, 1973; Craik & Lockhart, 1972). At the same time, this qualitative aspect presents a complex interpretive problem in analyses of quantitative data, as well as in ascertaining the precise nature of the qualitative differences. Unless different depths of analysis can be compared on the same metric, unknown sources of difference may confound results showing quantitative difference. This is one substantive argument

presented by critics of levels of analysis (e.g., Baddeley, 1978).

The major interpretive problem with the present results, that HR patterns were not readily comparable on a single dimension, such as magnitude of acceleration, is suggestive of a solution to the problem of equating different levels tasks. Heart rate patterns for sensory and semantic tasks differed in several aspects, including the maximum and minimum values, time at which directional shifts occurred, and magnitude of change. In contrast, the patterns reported by Shangi et al. were considerably more homogeneous, differing primarily in magnitude of change. This difference in pattern homogeneity may reflect the degree of similarity in the attentional processes required for analysis of sensory and semantic tasks. An empirical solution to the problem of task equivalency could possibly be derived with the current approach of linking various phasic changes with differing attentional processes. Presumably, two tasks that produce identical HR patterns rely on the same type, and degree of involvement, of attentional processes. Heart rate differences in any one phasic component may then be found to distinguish tasks on the attentional process corresponding to that phasic change. Tasks differing in several phasic components could indicate vast differences in attentional requirements and perhaps, the mechanisms by which the information was processed. Of course, this procedure would not be error free. The fact

that successive physiological measurements are not independent presents the problem of determining how the level of one heart beat or the interbeat interval influences the next, and whether these influences vary across HR phases or cognitive processes. However, solutions to these problems are well within the realm of current scientific technologies.

It should be noted that changes in HR variability also could be used to index effort since HR stabalization or a decrease in HR variability often occurs during attention-demanding tasks (Helsgrove, Ogilvie, & Furedy, 1979). While the present interest was in changes of magnitude as opposed to changes in variability, it might be fruitful to examine the effect of level of processing on shifts in HR variability.

Two basic assumptions underlay the HR hypotheses tested; that depth of processing could be differentiated on a measure of cognitive effort, and that phasic HR acceleration could serve as that index. The results presented suggest that the validity of the latter assumption may be dependent on the nature of the tasks and procedures tested. It was not possible to compare the sensory and semantic tasks since the HR pattern appeared to reflect differing attentional requirements at each level. However, foreperiod acceleration comparisons between targets and nontargets, processed in either the sensory or semantic mode, were possible and the results were consistent with the

basic underlying assumption. Overall, this assumption still appears to be a sound one since tasks involving cognitive elaboration (Cacioppo & Sandman, 1978), cognitive rehearsal (Dennis & Mulcahy, 1980), and high activity imagery (Jones & Johnson, 1980) each produce foreperiod HR acceleration, the magnitude of which corresponds to task difficulty.

The assumption that levels of analysis could be discriminated on cognitive effort was based on the notion that "deeper" levels require that more attention be "paid" (Craik, 1973), and that more elaboration of encoded inputs occur. Studies by Johnston & Heinz (1978) and others (Shangi et al. 1978) support this contention. A more recent study by Mulcahy & Dennis (Note 1) also showed that secondary probe reaction time, as a measure of the capacity demands of ongoing processing, increased with depth of analysis at the time when a response decision was being made. Failure to support these findings with HR differences may be attributed to problems of comparability of the different levels tasks studied.

This study has attempted to examine the effect of depth of processing on cognitive effort. The following study, which will explore the relationships between cognitive effort, selective efficiency, and reading proficiency in a levels of analysis task, may help to shed further light on the general problem studied here.

VI. STUDY THREE

Study three examined whether attention differences in effort expenditure and selective efficiency exist between poor, average, and proficient readers as a function of two levels of processing (sensory versus semantic) and, the presence or absence of an auditory distractor.

METHOD

Experimental Paradigm and Design

A divided attention paradigm (cf. Johnston & Heinz, 1978) requiring subjects to perform a selective listening task, and a subsidiary RT task concurrently, was used to compare poor, average and proficent readers under four selective listening conditions. Each condition required subjects to listen for, detect, and verbally state the presence of specified target words randomly located within a list of nontarget items. One-half of the Ss in each reading group listened for targets on the basis of a sensory cue (female vs male voice) while the remainder used a semantic mode (taxonomic category). Subjects listened to two blocks of nine lists. Block one was presented without a distractor whereas lists in the second block were presented simultaneously with a distractor list emanating from a different, and auditorily distinct location in the room. These conditions were designed to simulate the selective listening demands of a classroom.

Concurrent with the list presentation, a light signal requiring a button press response occurred in random

positions throughout each trial. Variable reaction times to this secondary probe stimuli indexed the capacity requirements of the primary selective attention task. Logically, the greater the capacity consumed by the selection process, the less residual capacity is available for signal detection, and the longer the latencies.

Subjects

Sixty, fourth and fifth grade students screened for normal intelligence were selected from the Edmonton Public School System. These grades were chosen since reading difficulties or proficiencies are clearly apparent by fourth grade (Hallahan, 1975), and 9 to 10-year-olds are sufficiently mature to respond to a divided attention task (Geffen & Sexton, 1978). Students were classified as poor, average, and proficient readers on the decoding subtest of the Elementary Reading Test constructed and administered by the Edmonton Public School System. Percentile ranges were 10-30, 40-60, and 70-90, respectively. Nonverbal IQ scores derived from the Canadian Cognitive Abilities Test (CCAT) were used in the selection criteria to ensure comparable intellectual levels between the groups. Group characteristics are shown in Table 6. Children scoring below 1.5 standard deviations on the CCAT were excluded. Children with evidence of emotional disturbance or organic brain damage also were excluded, as were those with uncorrected vision or hearing impairment. Between group comparisons indicated that the six groups (3 reading groups X 2 levels

Table 6

Reading Group Characteristics

Reading Level	Sample Size M	Sample Size F	Age Mean	Age SD	(a) IQ Mean	(a) IQ SD	(b) Decoding %ile
Poor	15	5	10.3	.8	98	11.0	24.5
Average	12	8	9.8	.8	99	11.1	51.0
Proficient	8	12	9.8	.97	105	8.3	79.5

[a] Canadian Cognitive Abilities Test

[b] Elementary Reading Test

conditions) did not differ in age ($F_{5,54} = .99$) or IQ ($F_{5,54} = 1.09$).

It should be noted that the proportion of grade 5 to grade 4 students was greater in the poor reading groups (6 to 4) than the average or proficient reading groups (4 to 6). While these ratios are not greatly different, the effect of reading level on the RT data could potentially be confounded if the reading groups, as a result of the grade composition, also differed in age since older children may process linguistic material more quickly (cf. Manis et al. 1980). Therefore, it was ensured that the reading groups were of comparable age. In fact, their mean ages were within six months of each other, and as noted previously, their ages did not statistically differ.

Apparatus and Stimuli

Two blocks of nine word lists (trials), and the distractor lists were randomly selected from a pool of 300 words representing nine taxonomic categories of the Rosch (1975) norms. These include: furniture, fruits, weapons, vegetables, tools, birds, sports, clothing, and vehicles. Each word list contained 25 words presented at the rate of one word every 2 secs. An average of two targets (range 1 to 3) occurred at random positions within each of the nine lists for a total of 16 targets per block. The first three word lists in each block of nine lists were practice trials, the remaining six lists were test trials.

Target words for sensory trials, and the nontarget words for all trials were randomly selected from all categories except vehicles. Six words from the category vehicles were reserved for targets on semantic trials since these words (e.g., bus, car) were found by Rosch to be more representative of their taxonomic category than words in any other category. This procedure was implemented in order to minimize possible effects of semantic ambiguity on cognitive effort. Sensory targets were spoken in one of two female voices, with nontargets spoken in one of four male voices. Voices were completely random on semantic trials.

The light source for the subsidiary RT task was projected through a 10 X12 cm. opaque screen mounted about 2 m. in front of the subject at about eye level. The light signal, with a duration of 200 msec., occurred five times during each trial; once during each ten sec. interval of each 50 sec. trial (25 words @ 1 word/2 sec.). A signal could occur in one of five positions within each interval, with the restriction that 3 secs must lapse between consecutive signals. Each position was marked 500 msec. following onset of a word. Cognitive effort during processing of the words was judged to be maximal during this period (cf. Manis et al. 1980). A schematic representation of a single trial is shown in Figure 3.

Word lists were studio recorded on a Sony TC-630 4-track recorder with the distractor lists recorded simultaneously on a separate channel. Polygraph tracings of

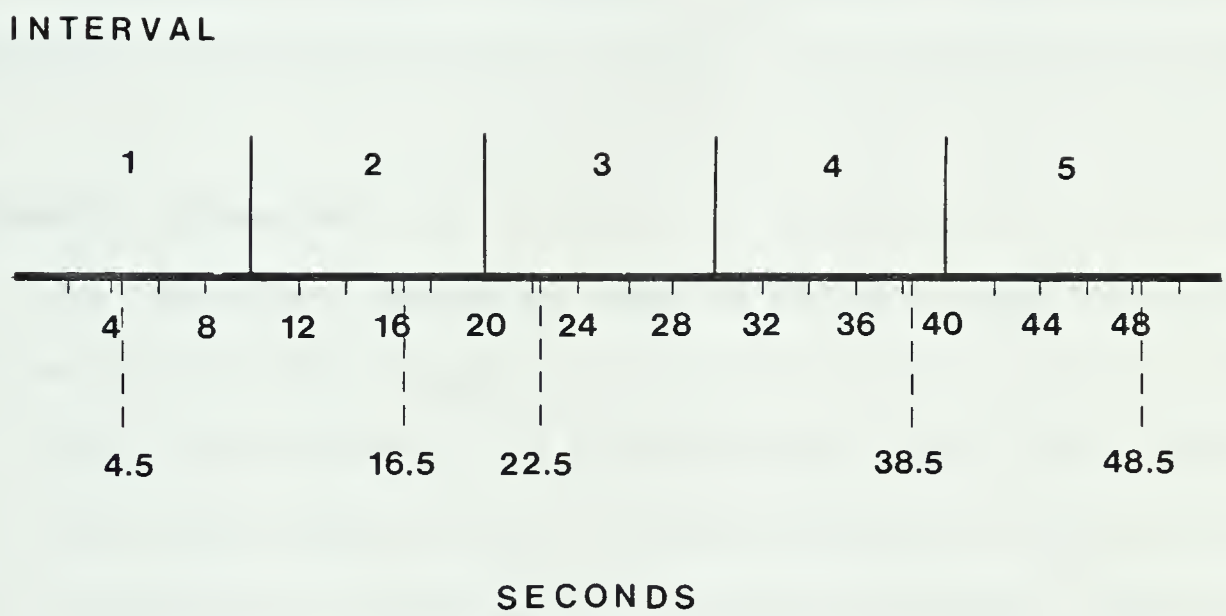

Figure 3. Schematic of a single trial presentation of 25 words presented at the rate of 1 word/ 2 secs. The tone, indicated by vertical dot-lines, occurred 500 msec. after word onset. During each of the 5 intervals, the tone could occur following any word determined at random.

the word onset times for simultaneous presentation on two channels showed that onset times never deviated more than 100 msec. The light signal for the secondary RT task, and a Lafayette 54417 RT clock, were automatically triggered by a relay sensitive to tones recorded on a third channel. These tones were inaudable. Word lists are shown in Appendix C.

The speaker for the target list presentation was located about 2 m. in front of the subject. The distractor list emanated from a speaker located approximately 45 degrees to the left of the subject at a distance of about 3 m.

Dependent Measures

Two dependent measures were obtained; cognitive effort and selective efficiency.

Cognitive Effort: The difference between the median RT to the light signal alone, determined prior to word trials, and the median RT recorded during each series, constituted the dependent measure of effort. Reaction times were not considered over intervals or trials since these have not been found diagnostically important (Johnston & Heinz, 1978). Data from the first three practice trials in each series and the first RT score of each trial in all subsequent trials were excluded in order to reduce RT variance due to warm-up or practice effects.

Selective Efficiency: This aspect of attention was measured in terms of percentage errors arising from failure to detect targets (omissions) or false detections

(intrusions).

Procedure

Individual testing took place in a small room in the school. Subjects were seated facing the light signal apparatus and students used their preferred hand for button-press responses. Subjects were informed of the list composition and the nature of the tasks prior to the practice trials, and before each set of blocked trials. Their task was to verbally state the target when it occurred, and make a button press in response to the light signal. The instructions emphasized that target detection was the primary task. Those participating in the semantic condition were required to memorize the target items in order to minimize group variations in mnemonic skill. Postexperiment target recall of 98% indicated that Ss had retained the target set.

Following task instructions and before practice trials, subject's RT to the light signal alone was assessed for fifteen trials. Signal timing followed the same format used during experimental trials. Median signal detection times for the last 10 signals for the poor, average, and proficient readers were .31 sec. (SD=.09), .32 sec. (SD=.05), and .32 sec. (SD=.05), respectively.

RESULTS

Cognitive Effort: Cognitive effort was measured as the difference between base RT and the median RT recorded while students listened to the word lists. Raw RT data is shown in

Appendix D. Subsequent analysis of the difference scores (Table 7) showed a significant interaction of reading group with level of processing ($F_{1,54} = 3.28$, $p<.05$), as well as main effects for both levels ($F_{1,54} = 15.09$, $p<.001$) and presence of a distractor ($F_{1,54} = 16.7$, $p<.001$). The absence of any interaction involving the presence or absence of a distractor clearly indicates that poor readers were no more influenced by a competing source of verbal information than were more skilled readers. Instead, the presence of a distractor increased the effort required to select both sensory and semantic targets for all reading groups.

Scheffe' post hoc tests indicated that readers differed only at the semantic level. The sensory task of selecting words on the basis of voice quality did not distinguish the reading groups in either secondary RT or percentage errors. As may be seen from Figure 4, average and proficient readers form a skilled reading group since they produce near identical RT scores. These skilled readers showed significantly longer response latencies, and therefore, more effort in response to the primary semantic selection task while the poor readers failed to do so. Furthermore, poor readers did not differ in their effort allocation patterns between the sensory and semantic tasks whereas both skilled groups expended less effort in the sensory mode.

The first three trials in each condition (practice trials) were not included in the data analysis. Instead, these data are shown in Appendix D. As expected, the

Table 7

Analysis of Variance of Secondary (Probe) RT

Source	df	MS	F
Between Subject			
Reading Grp	2	.001	.20
Levels	1	.104	15.09**
Grp X Levels	2	.023	3.28*
Subj W Group	54	.007	
Within Subject			
Distractor	1	.019	16.70**
Grp X Dist	2	.000	<1
Level X Dist	1	.000	<1
Grp X Level X Dist	2	.000	<1
Dist X Subj W Grp	54	.001	

* $p < .05$
** $P < .01$

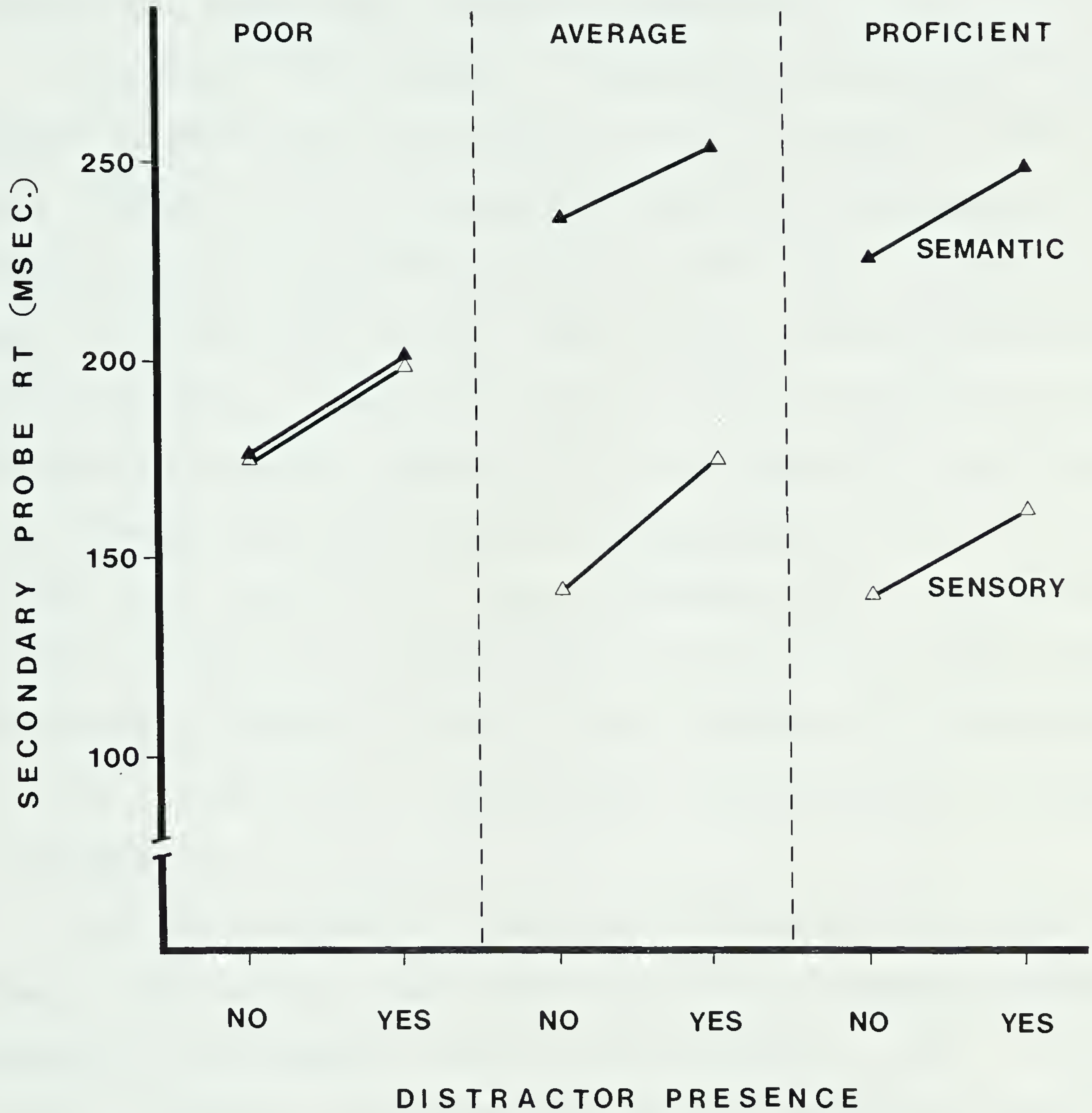

Figure 4. Cognitive effort of three reading level groups during sensory and semantic processing, and in the presence or absence of a distractor.

practice trial means are greater than the test trial means although the variability of the practice and test trial data appear similar. Overall, the practice trial data correspond to the test trial data across all conditions.

Selective Efficiency: Percentage omissions (i.e., missed targets) were analyzed in the same format as the RT data (Table 8). The percentage of omissions depended on the interaction of the reading group and the level of processing used (F 2,54 = 4.1, $p<.05$). While errors rarely occurred on sensory trials for any group, poor readers more often failed to detect targets on semantic trials (Figure 5). Significant main effects were obtained for reading group (F 2,54 = 4.1, $p<.05$), as well as for level of processing (F 1,54 = 64.9, $p<.001$). There was a tendency for all groups to make more omissions on semantic trials in the presence of a distractor (F 1,54 = 2.97, $p<.1$). Raw data for omission errors is shown in Appendix D.

Intrusion errors or false detections were few, occuring almost exclusively and with equivalent frequency between groups at the semantic level of processing (F 1,54 = 4.74, $p<.05$). Subjects averaged less than 2% intrusion errors in the semantic condition (Table 9).

To explore the questions concerning the relationship between reading proficiency and attention, Pearson's Product moment correlations were calculated between decoding skill (reading level), secondary RT (cognitive effort), percentage errors (selective efficiency), and IQ. These

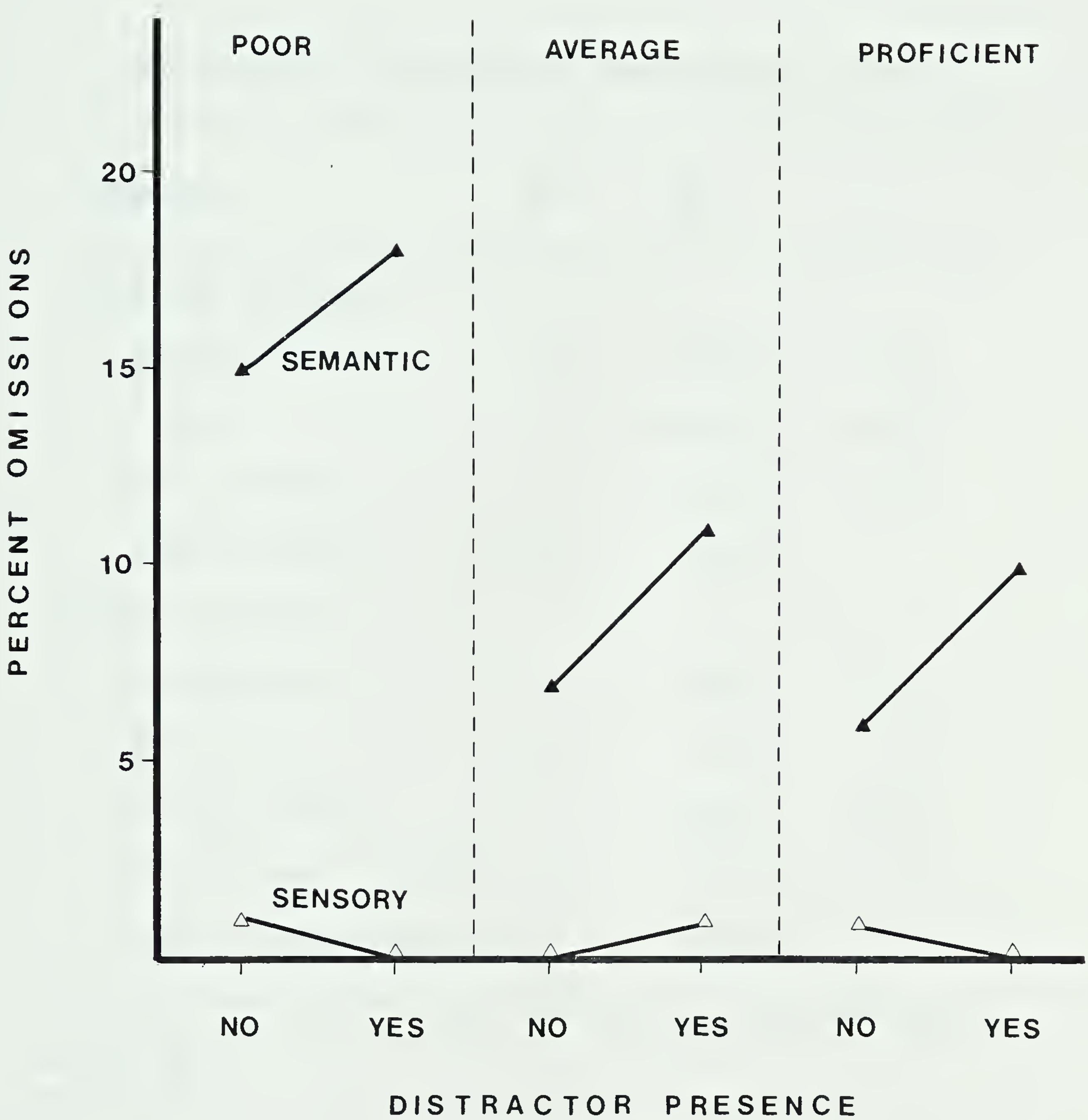

Figure 5. Selective efficiency of three reading level groups during sensory and semantic processing, and in the presence or absence of a distractor.

Table 8

Analysis of Variance of Percentage Omissions

Source	df	MS	F
Between Subject			
Reading Grp	2	215.8	4.10*
Levels	1	3413.3	64.90**
Grp X Levels	2	215.8	4.10*
Subj W Group	54	52.6	
Within Subject			
Distractor	1	83.3	2.06
Grp X Dist	2	5.8	.14
Level X Dist	1	120.0	2.97
Grp X Level X Dist	2	2.5	.06
Dist X Subj W Grp	54	40.43	

* $p < .05$
** $P < .01$

Table 9

Analysis of Variance of Percentage Intrusions

Source	df	MS	F
Between Subject			
Reading Grp	2	10.0	.57
Levels	1	83.3	4.74*
Grp X Levels	2	13.3	.76
Subj W Group	54	17.8	
Within Subject			
Distractor	1	.0	.0
Grp X Dist	2	.0	.0
Level X Dist	1	3.3	.31
Grp X Level X Dist	2	3.3	.31
Dist X Subj W Grp	54	10.9	

* $p < .05$
** $P < .01$

intercorrelations were determined for each level of processing across the distractor and no distractor conditions, and then repeated, partialling out the effect of IQ. Partial correlations were examined since small positive correlations existed between decoding skill and IQ in both the sensory (r=.26) and semantic conditions (r=.30). As may be seen from Table 10, the influence of IQ varied somewhat depending upon the condition, as well as the pattern of intercorrelations with the attention measures. In most instances IQ was only marginally correlated with RT and percentage errors. The low to moderate correlations obtained in both sensory conditions, and the no-distractor semantic condition, were reduced when IQ was partialled although only slight moderations were produced in the semantic distractor condition. Furthermore, the correlations obtained in the distractor and no-distractor conditions tended to be consistent within each level of processing.

The results of the correlational analyses shown in Table 10 indicate that the relationship between measures of attention and reading proficiency depends, in part, upon the level of analysis from which the data was derived. Secondary RT was negatively correlated with decoding skill in the sensory condition but positively related in the semantic condition. Skilled readers tended to expend less effort in order to select targets from nontargets on the basis of voice cue and more effort to make a semantic decision. Consistent with these results, skilled readers also tended

Table 10

Intercorrelations between secondary RT,
% error, decoding skill, and IQ.
No-distractor (1 list) conditions - lower left quadrant.
Distractor (2 - list) conditions - upper right quadrant.

Sensory Conditions

	RT	%Error	Decoding	IQ
RT		-.03 (-.04)	.36** (-.23)	-.14
%Error	.08 (.1)		.02 (.05)	.11
Decoding	-.39** (-.29)	-.02 (.02)		.26
IQ	-.06	-.21	.26.	

Semantic Conditions

	RT	%Error	Decoding	IQ
RT		-.24 (-.27)	.29 (.34)*	-.14
%Error	.00 (.08)		-.31 (-.36)**	-.14
Decoding	.38** (.26)	-.33* (-.04)		.30
IQ	-.15	-.48**	.29	

* p<.10 (two-tailed)
** p< .05

Note. Numbers in parentheses indicate correlations between the variables with IQ partialled out. N=30 in each levels condition.

to make fewer errors in semantic selection although this finding does not extend to the processing of sensory information since relatively few errors ever occurred in this condition.

The infrequency of sensory selection errors also accounts for the lack of any relationship between secondary RT and error rate in the sensory condition but a small to moderate negative correlation between these two variables was anticipated in the semantic condition. The observed r=.08 in the semantic no-distraction condition shows that selective efficiency (% errors) was independent of the effort expended in the task. A further analysis of the individual scores revealed that the range of errors was highly restricted, with over 75% of the Ss scoring in the 5%-15% range, while these same Ss spanned the full range of secondary RT's from 100 msec. to 310 msec. However, when the task became more difficult with the addition of a verbal distractor, and the frequency of errors increased, the expected relationship was obtained (r = -.27). Individuals who tended to make fewer errors also tended to expend more effort in the process of selecting semantic targets from nontargets. These results, in concert with the analyses of variance reported previously, indicate that attentional factors are relevant to the reading abilities of elementary school children.

DISCUSSION

The results of study three will be discussed in two sections. The first section addresses the issue of distractibility among poor readers and the second focuses on the specific attentional factors of cognitive effort and selective efficiency as these elements relate to reading skill.

Distractability

The hypothesis that poor readers are not differentially distracted by the presence of an auditory distractor (Nobre & Nobre, 1975; Pelham, 1979) was supported by the present results. The verbal distractor increased the effort demands of the target selection task, as well as the frequency of semantic selection errors but these effects were essentially the same for poor, average and proficient readers. It is apparent from the present study, as well as some others (e.g., Nobre & Nobre, 1975) that poor readers can effectively process and discriminate verbal auditory material in the presence of various auditory distractors. Since much of classroom learning requires attentive listening to a teacher's verbal presentation, and ignoring of competing auditory inputs, the data presented here are important in suggesting that poor readers are not disadvantaged in a typical classroom environment.

However, there is a body of evidence suggesting that poor readers and/or reading-disabled children are differentially distracted (Douglas & Peters, 1979). These

apparently conflicting conclusions suggest that differential distractibility effects are likely to be dependent on the type of task used to assess such effects, the type and characteristics of the task-irrelevant stimuli, subject characteristics, and perhaps, the associated experimental procedures. Unfortunately, there do not appear to be clear consistent results with regard to the particular stimulus conditions under which differentially distractibility effects can be found.

Some evidence for a differential distraction effect involved reading of words or stories (Samuels, 1967; Willows, 1974; 1975) but these results are difficult to interpret. As Ross (1976) has noted, poor readers may turn to the distractor when confronted with a reading task that may evoke an aversive reaction. In studies where the distractor, such as pictures, provides information complementary to the text (e.g., Samuels, 1967) attending to the distractor may even represent an adaptive strategy since it might enable the poor reader to extract additional context information that would facilitate text comprehension. Differences in task strategy also may account for differential distractibility effects with other tasks. The most recent work by Pelham (1979) provides no evidence of distractibility on central-incidental learning tasks. Rather, differences in task approach and memory strategies may account for the relative differences in the degree of incidental learning or the ratio of incidental to central

learning that are used as indices of distractability. Some studies show that normal readers may recall more task-irrelevant incidental information (Deikel & Friedman, 1976) and the oft found superiority of normal readers to recall more task-relevant central information may simple reflect a difference in memory or some other aspect of information processing, and not distractability (Pelham, 1979).

The contradictory results between distraction studies with poor readers and/or reading-disabled children suggests that distractability effects involve complex interactions of task parameters and experimental procedures if, in fact, such effects are not simply artifacts arising from differences related to other aspects of information processing. In a review of distractability studies with hyperactive children, Douglas and Peters (1979) noted that tasks involving reading or other academic material may confound motivational differences with performance differences. Ross (1976) also argued in favor of this view. In more general terms, any performance difference between groups on the relevant task could confound the results. If such differences exist, then adding irrelevant stimuli may place a further load on the information processing system, thereby adversely affecting performance on the relevant task more for the disadvantaged group (Douglas & Peters, 1979). Secondly, performance differences on some tasks, such as the central-incidental learning paradigm, may be attributed to

differences in other aspects of information processing (Pelham, 1979). In any case, it seems that distractability is not a ubiquitous characteristic, if present at all, among children who do not read well.

Cognitive Effort and Selective Efficiency

On measures of cognitive effort and selective efficiency, significant differences were observed between skilled and unskilled readers at deeper levels of processing. Comparisons between reading groups showed that poor readers missed more target items and invested less effort in the selection task requiring a semantic mode. In contrast, poor readers tended to invest more effort in sensory selection. The correlational analysis further indicated that, at the semantic level, higher levels of effort were associated with fewer selection errors.

At a general level, these results are supportive of the proposition that reading decoding failure may represent a special case of language decoding failure (Perfetti & Goldman, 1976; Perfetti & Lesgold, 1978; Piontkowski & Calfee, 1979; Vellutino, 1977) since the task here involved listening and not reading. The questions to be addressed at this point, then, concern the nature of such a relationship between reading and language, and in particular, how the attentional factors of effort and efficiency are related to reading or language processes.

The results of the present study are particularly relevant to the theory that readers differ fundamentally in

their ability to encode linguistic inputs (Perfetti & Lesgold, 1978). This difference might be reflected in differing effort allocation patterns, and lowered selective efficiency for unskilled readers, particularly when the task involves a more complex or elaborate level of analysis. In terms of selective efficiency, the percentage of omission errors was significantly greater for poor readers at the semantic level of analysis. This evidence corroborates the assertion that poor readers experience difficulty in short-term linguistic encoding, and in particular, the view that information is not processed efficiently in working memory (Daneman & Carpenter, 1980). Error rates, however, did not differ as a function of reading skill at the more "shallow" level of sensory analysis as error rates were uniformly low.

This distinction between the two levels or modes of processing may be linked, in part, with the effort demands associated with each level. In accord with the attention demand hypothesis described prviously, decreases in selective efficiency would be greater with tasks that placed heavy demands on working memory. This effect would be magnified for the poor reader if, in fact, automaticity in linguistic encoding had not reached the level achieved by the skilled reader. Evidence for this position in the present study may be drawn from the observation that poor readers tended to invest more effort at the "shallower" level of sensory analysis. Assuming an upper limit on

available processing capacity, a poor reader would have less capacity available for the more complex and effortful decisions required in a semantic mode and differential degrees of selective inefficiency would emerge. The greater effort demands of a semantic processing mode were demonstrated in the significantly higher amounts of effort allocated by both average and proficient readers, and when the selection task was made more difficult with the addition of a distractor, effort expenditure, as well as error rates, increased even more.

However, it might also be expected that poor readers would invest more effort in the semantic task for the reason ascribed above; that is, if poor readers process information less efficiently then more effort would be needed to compensate for the difference. The fact that poor readers invested less effort when it seems more was needed for optimal performance suggests the possibility of another source of difference. Poor readers may have "shut-down" processing operations much too soon because they were not aware of the specific situational demands requiring more or less effort allocation. This point was precisely made by Piontkowski and Calfee (1979) who stated that the "... skilled reader knows when a situation demands concentration and when it is "safe" to process information automatically" (p.316). Particulary under conditions of some complexity, poor readers may not be aware of how to effectively distribute their attentional resources (Perfetti & Goldman,

1976). Thus, the difference between skilled and unskilled readers may exist not only in their proficiency of information processing but also in knowing how best to utilize available resources in order to achieve an optimal level of performance. The latter hypothesis is one which has received a considerable degree of empirical support in studies of the developmental course of metamemory (Brown, 1975; Chi, 1976) and metalinguistics (Hakes, 1980). The basic tenet of this work is that over the course of development, performance increments are, in large measure, attributable to more efficient use of the resources of a limited capacity system via greater awareness and availability of strategies and techniques for efficient information processing (Chi, 1976; Forrest & Waller, 1979).

One last consideration of the results concerns the possibility that skilled and unskilled readers differ in some other systematic way; either in motivation or their approach to the divided attention task or in their ability to retain the semantic target set they were asked to rehearse prior to the experiment. Reaction time differences between the reading groups would occur if one group devoted more or less attention to the secondary RT probe relative to the primary listening task. For example, the faster RT's of poor readers in the semantic condition may have resulted from a tendency to watch the secondary probe more closely. Such a possibility is difficult, if not impossible, to either verify or refute in context of the present study.

However, such priority differences would be expected to occur for both sensory and semantic processing modes; showing faster RT's by poor readers in each test situation. The absence of such an effect suggests that differences in task approach, if any, did not account for the differential RT's. Motivational differences could possibly have played a part but, again, the RT scores do not conform to such an interpretation since longer latencies would be expected. Although no direct or indirect evidence was found for these alternative hypotheses, the possibility of a motivational or task-approach difference is deserving of further empirical examination.

Differences in RT and percentage omissions also could occur if poor readers failed to retain the set of semantic target words during the course of the experiment. This was not the case since all groups were able to recall successfully the set of items in a postexperiment recall test. The average target recall was 98% among all groups in the semantic condition.

In summary, the evidence presented in study three indicates that poor readers are not differentially distracted by verbal competing messages but poor readers do differ from their skilled counterparts in the attentional factors of cognitive effort and selective efficiency. These attentional differences were viewed as supporting the theory that poor readers experience difficulty in short-term linguistic encoding processes involving inefficiences in

effort allocation and working memory. Moreover, it seems that attentional inefficiency arises at higher levels of processing; in thinking of meaning rather than simple processing of the physical characteristics of what is heard; or when the task places a heavy demand on the limited capacity of working memory.

This discussion concludes the presentation of the studies conducted. A general discussion of the significance of these findings for the role of attention in levels of processing will be presented in the next section.

VII. GENERAL DISCUSSION

Breadth of Attention and Levels of Processing

The results of study one failed to support the hypothesis by Johnston & Heinz (1978) that breadth of attention differentially increases with depth of processing. Recognition of semantically encoded words did not differentially increase, neither when attention was divided between two sources of information, nor when attention was focused on one source to the relative exclusion of the other. Furthermore, the results of study three were consistent with these findings. A greater expenditure of effort was observed in response to increases in nontarget density but this effect was equivalent between the sensory and semantic conditions. Such consistent observations strongly indicate that the degree to which information is unintentionally extracted from nontarget inputs or irrelevant sources of information does not differentially change with depth of encoding.

The importance of these findings concerns the role of depth as a factor which may influence the probability of information from nontarget or unattended sources gaining entry into conscious awareness. Previous investigations have shown that information held to be pertinent to current decision making (Corteen & Wood, 1972) or particular inputs that may produce a conditioned attention response, such as one's name, come to the level of awareness even if such inputs were not monitored intentionally (Moray, 1959). The

conclusions of Johnston and Heinz (1978) were to suggest that this effect is modulated by depth of encoding, with less sensitivity to inputs encoded at shallower depths. This conclusion is refuted by the results of the present studies, demonstrating instead that breadth remains fairly uniform across different depths of processing as tested in an incidental learning paradigm. However, it may be possible to show breadth effects in an intentional learning situation, although these effects may be opposite to the predictions of Johnston and Heinz. Greater breadth may be achieved at shallower depths, rather than at deeper levels, since the lessened effort demands of encoding at shallower levels could permit processing of a greater number of such inputs.

While the data presented here suggest that breadth of attention does not differentially influence the memorability or effort demands of sensorially or semantically encoded inputs for children or adults with at least average intelligence, breadth effects may be a source of individual differences. For example, Ullman (1974) has shown breadth of attention to be related to intelligence, with TMR children showing less breadth of attention than EMR children or those with average intellectual ability. Therefore, the influence of depth of processing on breadth of attention may be significant to the outcomes of the attentional processes of mentally retarded individuals, and perhaps, other populations as well.

Cognitive Effort and Levels of Processing

The secondary RT results of study three support the hypothesis that cognitive effort or demands on capacity increase with depth of processing. These results concur with those of Johnston and Heinz (1978; 1979) and others (Eysenck & Eysenck, 1979) in supporting the original notion by Craik (1973) that greater attention is required as the perceptual processing system shifts from shallower to deeper encoding levels.

Since the amount of attention "paid" to a stimulus was identified as one criterion of depth (Craik, 1973), the present work was undertaken to assess, in part, both a physiological and behavioral measure of cognitive effort, as well as the notion that cognitive effort might serve as an independent index of depth. Study three results support the use of secondary RT as an independent index. Reaction time increased wth depth and task difficulty when a distractor was added to the original selection task. Eysenck and Eysenck (1979) also showed that when the elaborativeness or amount of processing required within a level of processing is increased, thereby increasing demands on capacity, secondary RT accurately reflects these changes. However, this measure is not without limitations (Duncan, 1980; Kerr, 1973). There is a risk of specific interference effects between the primary and secondary task although such effects were not found in the single study which empirically addressed this issue (Eysenck & Eysenck, 1979). There may be

limits on the types of tasks or paradigms for which capacity limitations can be said to account for performance differences (Duncan, 1980), and as discussed previously, RT differences between intact groups, such as skilled versus unskilled readers, could occur if these groups systematically differed in their task approach by virtue of intent or motivation. But with these limitations in mind, secondary RT may serve as a valuable tool.

Using magnitude of accelerative HR change as a measure of effort expenditure appears more complicated since phasic HR changes may reflect different attentional processes which may vary across tasks. Some distinctions noted in the previous discussion included the possibility of HR differences as a function of input modality, simultaneous versus successive processing strategies, timing of the response decision in a fixed-foreperiod paradigm, and the type of information intended to represent a particular level of processing, such as letter frequency versus letter size as representative of sensory tasks. In a recent review, Carroll and Anastasiades (1978) noted some of these problems and others in their statement that, "... the relationship between heart rate and attention is variable and heart rate is associated with factors other than attentional requirements" (p. 249). The problem, then, becomes one of refining our understanding of the relationship between various HR components and attentional or other processes that may be involved in levels of analysis. For example, a

correlational study of the relationship between phasic HR components and secondary RT might provide some useful information by highlighting those components associated with the behavioral RT measure of cognitive effort.

The empirical and theoretical import of the present work concerned the use of cognitive effort as an independent index of depth, and in general terms, the role of attention in levels of processing. Study three results indicated that cognitive effort can serve as an index of depth. However, depth implies more than simple cognitive effort. Effort is only one dimension of depth; a concept which also considers the meaningfulness or compatibility of the stimulus with the analyzing structures, and stimulus intensity or salience (Craik, 1973). Some hint as to the qualitative complexities involved in comparing different depths of processing can be taken from the distinctive HR patterns illustrated in study two. In view of these considerations, and to turn a phrase from Carroll and Anastasiades (1978), a depth taxonomy based only on cognitive effort would seem insufficiently sophisticated. Nevertheless, effort is one quantifiable aspect which almost consistently differentiates depth of encoding, where depth has been determined a priori on the basis of the apparent semanticity of encoding demanded by the task.

A further consideration of cognitive effort concerns its relationship to memory since the concept of depth was originally invoked as an explanatory variable intended to

account for some of the variability in memory performance. As noted by Griffith (1976), the relationship between effort and memory performance is a complex one because there are many factors which will influence memory performance in a levels of analysis task. Elaborativeness or richness of encoding (Eysenck & Eysenck, 1979), salience of the input (Craik, 1973), and the degree of correspondence between initial encoding cues and subsequent retrieval cues (Tulving, 1979) are some important factors. Thus, different modes need not be evaluated in terms of their effort demands in order to account for memorability but cognitive effort may be an important attentional factor in many situations. Its significance can readily be appreciated in those studies which have shown a positive relationship between effort expenditure and recall performance (Griffith, 1976; Tyler et al. 1979). Correlational data from study three also showed that effort expenditure was negatively correlated with omissions in target selection when task demands were greatest. Given that one is not likely to remember an item that has not been detected, cognitive effort assumes an important role in memory performance.

It has been suggested, however, that semantic encodings could be made with a minimal expenditure of effort because of an extensive "protracted experience" (Eysenck & Eysenck, 1979) or a high degree of familiarlity that permits a relative automaticity of processing (Shiffrin & Schneider, 1977). This point is not argued. Rather, it is suggested

here, as it is elsewhere (Hasher & Zacks, 1979), that a broad range of memory phenomena involve processes which are effortful. Furthermore, automatic processes or operations are ones which, by definition, place minimal demands on the limited capacity system. But as may be seen from study three and several other reports (Eysenck & Eysenck, 1979; Posner & Snyder, 1975; Tyler et al. 1979), levels of analysis tasks involve the expenditure of effort precisely because these tasks emphasize analyzing operations or controlled processes.

From a broad theoretical stance, the evidence presented supports a levels of analysis formulation of memory (Craik, 1973; Craik & Lockhart, 1972), as well as "capacity" theories of attention (Kahneman, 1973). The findings reported in study three also may be seen to make an important contribution to our understanding of the role of attention in reading. This aspect will be discussed in more detail in the next section.

Attention and Reading Proficiency

The two major findings of study three were that changes in effort expenditure and selective efficiency resulting from the presence of an auditory distractor were equivalent across three levels of reading proficiency, and skilled readers of average or above average proficiency showed a greater expenditure of effort and fewer selection errors in response to a semantic selection task relative to their unskilled counterparts. On the basis of these findings, the

previous discussion on the role of attention in reading emphasized three main points. The first point concerned the distractibility of poor readers. Distractability studies present such contradictory results that it is difficult to ascertain under which conditions, and for what types of activities distractability effects will occur. In their review of distractability studies, Douglas and Peters (1979) have stated that,

> "It is impossible to say at this time whether or not LD children have a primary distractability problem,..., (although) the LD child's learning disabilities could lead to pseudo- or secondary attentional problems" (p. 233).

Differential distractability effects were not found between skilled and unskilled readers in the present study but whether these results would be found across grade or age levels or for children with more severe forms of reading failure is an empirical question. An increased vulnerability to intrusions may be observed among children with more severe disabilities or with increasing age as failure experiences accumulate, and possibly, avoidance behaviors become more pronounced.

Similarly, task variables need to be considered since distractability effects may be task- or situation-specific. If inattentiveness or distractability occurs when the child is working on a task on which they have failed for reasons of their disability (Ross, 1976), then distractability may

be limited primarily to these specific tasks. This possiblilty may account for some of the discrepancies reported in the literature.

In summary, it would appear that distractability is not a generalized characteristic of children who do not read well. Future research, therefore, might seek to isolate the tasks, conditions, and individual variables which influence the susceptibility of poor readers or reading-disabled children to irrelevant or distracting stimuli.

The second and third points of emphasis in the previous discussion concerned the different effort allocation patterns between skilled and unskilled readers. Here it was suggested that poor readers are less efficient information processors, both in terms of their ability to encode linguistic material in working memory and to optimize their use of the resources of a limited capacity system. Thus, the source of difference between skilled and unskilled readers may be found in both bottom-up or data-driven processes and top-down or knowledge-driven processes.

Bottom-up processes refer to lower level coding processes ",,, whereby words are perceived and their meanings made available to higher level processes (Lesgold & Perfetti, 1978, p. 323). Poor readers in the present study tended to expend more effort in the processing of information at a shallower level of analysis, and selection efficiency decreased at a deeper level. These results were interpreted as supporting an attention-demand hypothesis;

failure to establish automaticity in lower level encoding and recoding of linguistic material produces a back-log of stored information and reduces the amount of capacity available for higher level processes (Curtis, 1980; Goldman, Hogaboam, Bell & Perfetti, 1980; Perfetti & Lesgold, 1978).

Data from study three also suggested that poor readers failed to achieve an optimal level of performance because of an inefficient use of the limited capacity attentional system. They failed to invest more effort when the attentional demands of the task increased at a semantic level of analysis. Thus, the information processing inefficiencies of poor readers may involve top-down processes of attention or knowledge of how best to use the available resources of a limited capacity system (Perfetti & Goldman, 1976; Piontrowski & Calfee, 1979). What the present study shows is something of the interaction between mode or level of processing and bottom-up and top-down processes. Specifically, top-down processes appear to be more crucial at deeper levels of analysis, when the complexity and effort demands of the task increase. The efficiency of bottom-up processes will influence the availability of capacity for higher-order processes, such as comprehension. Both aspects are crucial to the study of individual differences in cognition and reading (Carr, 1981), and the study of cognitive effort appears to allow access to both bottom-up and top-down processes and their interaction.

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APPENDICES

APPENDIX A
Study One Materials

Study One: Part A Practice Trials

One List Trials	Two List Trials	
picture	picture	bathrobe
sprouts	sprouts	brush
jumper	jumper	girdle
couch	couch	jack
awl (bus)	awl	(bus)
mirror	mirror	varnish
stand	stand	case
screws	screws	clock
square	square	cane
nylons	nylons	vanity

Note. Words in parentheses were substituted in semantic trials. The adjacent word "awl", spoken in a female voice, was the target on sensory trials.

Study One: Part A Test Trials

One List Trial		Two List Trial	
carrot		carrot	table
plane		plane	corn
vest		vest	bean
desk		desk	blouse
cucumber		cucumber	tomato
lettuce		lettuce	spinach
hammer		hammer	pillow
chisel		chisel	olive
rocker		rocker	sock
shirt (car)	(car)	shirt	stool
dress		dress	glove
beet		beet	vice
pea		pea	belt
lathe		lathe	boot
chest		chest	level
saw		saw	garlic
coat		coat	pepper
jacket (truck)	(truck)	jacket	pliers
chair		chair	pencil
hat		hat	pants
shoe		shoe	stove
bed		bed	lamp
drill		drill	square
potato		potato	sander
suit		suit	onion
sofa		sofa	rug

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

Study One: Part A Recognition Test

drill*	shelf	bureau	onion*
bench	plane*	hatchet	anvil
cabinet	sofa*	sock*	bean*
skirt	squash	level*	corn*
chair*	apron	pepper*	rule
saw*	ladder	leek	raincoat
vest*	scarf	parsley	pants*
lettuce*	sweater	table*	garlic*
cucumber*	dress*	lamp*	stool*
wrench	chisel*	sander*	slacks
desk*	lathe*	rhubarb	tomato*
file	wedge	mushroom	scissors
suit*	coat*	axe	square*
beet*	potato*	vice*	parsnip
carrot*	shoe*	blouse*	wood
pea*	brace	slip	sandal
hat*	broccoli	spinach*	rug*
rocker*	bed*	stove*	footstool
lounge	hammer*	yam	belt*
chest*	cauliflower	glove*	olive*
celery	cape	boot*	knife
turnip	buffet	bookcase	drawers
tie	piano	pillow*	dresser
radish	nails	pencil*	slipper
		pajamas	counter
		pliers*	cupboard

Note 1. Words marked by an asterisk (*) are experimental words. All others are distractors.

Note 2. The recognition test for Part A one list conditions consisted of only the two left columns. All four columns were used in two list conditions. In Part B, the two left columns were administered first as these contained the attended word list. A second recognition test consisting of the two right columns containing the unattended word list followed.

APPENDIX B
Study Two Materials

Study Two: Practice Trials

Sensory

chest	(garlic)
hat	awl
lathe	canoe
(plane)	stove
olive	glove

Semantic

chest	garlic
hat	awl
lathe	(canoe)
(plane)	stove
olive	glove

Sensory/Semantic

chest	garlic
hat	awl
lathe	(canoe)
(plane)	stove
olive	glove

Note. Target words are shown in parentheses.

Study Two: Test Trials

Sensory		Semantic		Sensory/ Semantic	
(chair)	belt	chair	belt	chair	belt
lettuce	(truck)	lettuce	(truck)	lettuce	(truck)
vest	rug	vest	rug	vest	rug
(suit)	jeep	suit	(jeep)	suit	(jeep)
dress	(bus)	dress	(bus)	dress	(bus)
desk	lamp	desk	lamp	desk	lamp
(shoe)	corn	shoe	corn	shoe	corn
carrot	spinach	carrot	spinach	carrot	spinach
bed	(car)	bed	(car)	bed	(car)
rocker	train	rocker	(train)	rocker	(train)
sock	(blouse)	sock	blouse	sock	blouse
sofa	boat	sofa	(boat)	sofa	(boat)
coat	ship	coat	(ship)	coat	(ship)
(table)	pepper	table	pepper	table	pepper
pea	(van)	pea	(van)	pea	(van)
boot	onion	boot	onion	boot	onion
pants	pillow	pants	pillow	pants	pillow
potato	(taxi)	potato	(taxi)	potato	(taxi)
bean	stool	bean	stool	bean	stool
beet	jet	beet	(jet)	beet	(jet)

Note. Target words are shown in parentheses.

Study Two: Recognition Test

yam	lettuce*
cabinet	drawers
spinach*	skirt
sofa*	piano
coat*	corn*
broccoli	rocker*
tie	desk*
cupboard	parsley
potato*	pea*
parsnip	counter
turnip	slacks
pants*	bookcase
raincoat	bean*
cauliflower	lamp*
vest*	boot*
rug*	leek
dress*	bed*
onion*	pepper*
slip	bench
belt*	squash
beet*	pillow*
shelf	mushroom
cape	stool*
celery	sock*
sandal	carrot*

Note. Words marked by an asterisk (*) are experimental words. All others are distractors.

APPENDIX C
Study Three Materials

Study Three: No Distractor Practice Trials

1	2	3
rocker	woodpecker	blueberry
prunes (bus)	sandals	tennis
club	fig	softball
gym	rug (truck)	purse
cement	pliers	crow
cards	hatchet	title
football	boots	canoe
dishes	ball	fists
shirt (jeep)	rope	knife
dove	lacrosse	sprouts
nut	skiing	hunting (auto)
stereo	golf	owl
desk	surfing	hockey
mirror	boat	rice
lemon	poison (van)	water
raisin	slacks	whip
scarf	sandpaper	date
radio	goose	onion
pickles	tie	wood
plane	olive	radish
bureau	pigeon	sander
rifle (car)	sparrow	bookcase
dandelion	crane	leek
wrestling	banana	carrot

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

Study Three: No Distractor Test Trials

4	5	6
socks	pistol	cucumber
cauliflower	vase	parka
grenade	closet	teddy
nails	vest (truck)	saw
earrings	shoes	rope (car)
duck	cupboard	pistol
beets	peach	raincoat
stone	redbird	ring
bullet (bus)	belt	shelf
dresser	bomb	chest (jeep)
stove	sword	vanity
watermelon	shotgun	watch
drill (van)	dagger	potato
ladder	bed	balloon
stick	penquin	drawers
rock (auto)	marbles	glue
lettuce	fan	pineapple
squash	rags	hat
falcon	ruler	slip
tomato	rocket	blade
parrot	shelf	seagull
grapefruit	checkers	chain
swallow	pillow	sled
drapes	lifting	animal
skirt	pajamas	asparagus

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

Study Three: No Distractor Test Trials

7	8	9
toy	parsley	tape
cape	hinge	swimming
pumpkin	crowbar	beans (van)
seaweed	screwdriver	can
arrow	buffet	bar
house	running	pumpkin
parsnip	camping (bus)	baseball
scissors(truck)	slippers (car)	bench
bluebird	broccoli	orange
turnip	bolts	sofa
level	table	paper
basketball	cushion	revolver
stork	bat	garlic
celery	rowing	gas
chess	game	lime
train	block	eagle
tricyle	spear (jeep)	cannon
crayons	hawk	dancing
wagon	raven	missile
chicken	coat	berry
peanut	dress	track
rattle	drum	boxing
doll	wren	chisel (auto)
gloves	lounge	strawberry
puzzle	swan	jumper

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

Study Three: Distractor Practice Trials

1		2	
Distractor List	Target List	Distractor List	Target List
raincoat	peach	bullet	rattle
parrot	pea	cupboard	arrow
shoes	chalk	cricket	bathrobe
rocker	ball	suit	hammer
pickle	crayons	cannon	mittens
greens	dagger	camping	radio
slippers	dishes	teddy	chair
hiking	ladder	bed	chicken
axe	sofa (car)	turnip	swimming
blouse	seagull	pelican	gym
raisin	turkey	grapes	woodpecker
raspberry	fishing	fan	blade
nut	cement	bench	cucumber
berry	sword	rifle	shotgun
dandelion	earrings	vest	wrestling
kite	skiing	hockey	pepper
skates	owl (jeep)	garlic	nylons
eagle	sparrow	falcon	sailing
mushroom	rowing	hunting	softball
crane	football	pliers	lifting
rug	chess	glove	parka (truck)
peanut	lamp	piano	horse
saw	top	wagon	cabinet
stool	brush	dove	slide
purse	judo	pajamas	raven

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

Study Three: Distractor Practice Trials

3

Distractor List	Target List
watermelon	rocket (auto)
socks	rags
bear	gun
bureau	bluejay
tricyle	celery
pumpkin	lounge
swing	sandpaper
date	pigeon
onion	dancing
parsnip	beans
strawberry	drawers
drum	club
tie	golf (bus)
radish	seaweed
chisel	olive
bar	plum (van)
blueberry	cushion
seaweed	slacks
running	wrench
tennis	peacock
vase	rope
stereo	boots
train	ring
stork	bolts
hatchet	bowling

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

Study Three: Distractor Test Trials

4		5	
Distractor List	Target List	Distractor List	Target List
raspberry	revolver	bullet	fishing
grapes	revolver	stove	seaweed
fan	ladder	beets	diving
wagon	mittens	duck	wood (van)
peanut	cucumber	wrestling	blueberry
bench	dagger	seagull	onion
piano	slip	turkey	date
saw	shotgun	blade	whip
stool	shelf	sword	penguin
purse	chest	chair	skating (truck)
dove	rhubarb	gloves	bowling
nut	sander	grenade	racing
rifle	hat	cauliflower	books
dandelion	pineapple	parsley	swing
vest	glue	belt	pear
crane	earrings	suit	pumpkin (bus)
screws	dishes	cherry	razor
raisin	football	redbird	parsnip
pajamas	softball	running	level
parrot	rowing	squash	strawberry
pelican	sparrow	turnip	baseball
peach	cement	chisel	scarf
cupboard	gym	drum	tricycle
shoes	sailing (car)	asparagus	grapefruit
clay	radio	ring	bar

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

Study Three: Distractor Test Trials

6		7	
Distractor List	Target List	Distractor List	Target List
cards	golf	socks	rice
jumper	plum	watermelon	apron
raven	water	hawk	banana
apear	bomb	apricot	pickle
sandals	cannon	plane	crow
canoe	chalk	pickles	tile
broccoli	arrow (auto)	nails	square
goose	table	game	tie
stick	pool	rock	ruler
radish	pencil	sandpaper	seaweed
swan	bed	lounge	melon
block	beans	celery	raincoat
missile	hiking	bluejay	axe
paper	cricket	rocket	toy
couch	volleyball	gun	prunes
hatchet	marbles	stork	drawers
rags	olive	stove	lettuce
shirt	dancing (jeep)	basketball	pigeon
dresser	corn	crane	pumpkin
pliers	paint	rug	tape (car)
jacket	poison	puzzle	bolts
bluebird	tank	rattle	cushion
hunting	slacks	doll	bat
knife	animal	bathrobe	club
blouse	wrench	surfing	boat

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

Study Three: Distractor Test Trials

8		9	
Distractor List	Target List	Distractor List	Target List
skiing	gas	crayons	tomato
pepper	pants	pea	dress
hammer	pistol	sofa	coat
owl	fig	swimming	desk (auto)
nylons	scissors	greens	mirror
chicken	stapler	boxing	lemon
bow	chain	track	hinge
balloon	house	cranberry	crowbar
woodpecker	carrot	bricks	screwdriver
bureau	leek	sprouts	buffet
drill	geese (truck)	train	wren
apple	cape	footstool	berry
tennis	skirt	blackbird	stereo
closet	salt	sweater	pillow
vase	checkers (jeep)	bookcase	rocker
bear	bench	top	camping (bus)
spinach	canary	shelf	slippers
cabinet	robin	lamp	teddy
slide	drapes	lime	kite
brush	swallow	parka	hockey
judo	potato	house	skates
lacrosse	orange	fists	garlic
lifting	watch	boots	eagle
chess	vanity (van)	peacock	falcon
ball	sled	rope	mushroom

Note. Words in parentheses were substituted in semantic trials. Adjacent words were spoken in a female voice in sensory trials.

APPENDIX D
Study Three Raw Data

Study Three

Omission Errors: Means and standard deviations for each reading group in all conditions.

	Sensory				Semantic			
	No Dist		Dist		No Dist		Dist	
Reading Group	M	SD	M	SD	M	SD	M	SD
Poor	.01	.03	0	0	.15	.09	.18	.13
Average	0	0	.01	.03	.07	.11	.11	.07
Proficient	.01	.03	0	0	.06	.07	.10	.07

Study Three

Secondary Reaction Time: Means and standard deviations of the difference scores (test trial RT minus base RT) in seconds for each reading group in all conditions.

	Sensory				Semantic			
	No Dist		Dist		No Dist		Dist	
Reading Group	M	SD	M	SD	M	SD	M	SD
Poor	.176	.06	.199	.07	.177	.07	.206	.05
Average	.141	.05	.175	.04	.235	.07	.254	.09
Proficient	.140	.06	.162	.06	.226	.04	.248	.08

Study Three: Practice Trials

Secondary Reaction Time: Means and standard deviations of the difference scores (practice trial RT minus base RT) in seconds for each reading group in all conditions.

	Sensory				Semantic			
	No Dist		Dist		No Dist		Dist	
Reading Group	M	SD	M	SD	M	SD	M	SD
Poor	.225	.09	.241	.06	.197	.09	.256	.05
Average	.180	.03	.210	.04	.233	.08	.255	.06
Proficient	.160	.08	.170	.07	.252	.04	.263	.06